

A commercial airplane is shown in flight, viewed from a low angle, flying towards the right. The sky is a clear, pale blue with scattered white clouds. The airplane's wings and tail are visible, and it appears to be a large passenger jet.

Aircraft, Automotive & Other Products Using Polymer-Matrix- Reinforced Plastics

Professor Chris Chatwin
University of Sussex

<http://www.sussex.ac.uk/profiles/9815>



F22 Raptor





First Flight 2.5 years late; December 15, 2009.



Fuel Efficient



The design incorporates some of the advanced design features developed for the Sonic Cruiser concept, including increased use of lightweight composites and advanced aluminium alloys, making the aircraft more fuel-efficient and environmentally friendly

Boeing 787 Dreamliner

- The Dreamliner is the first commercial aircraft to be made mainly of carbon fibre rather than aluminium, making it lighter and more fuel-efficient.
- The advance has been keenly awaited by airlines that have struggled with the soaring price of oil in recent years.

Performance

- The 787 family of aircraft, in the 200 to 300-seat class, will carry passengers non-stop on routes between 6,500km and 16,000km at speeds up to Mach 0.85.
- The aircraft is highly fuel-efficient and offers lower cost of travel in terms of **seat cost per mile** as well as the ability to fly directly to smaller regional airports

Market Positioning



The 787 is able to fly directly to smaller airports avoiding the need for passengers to transfer flights to reach regional destinations, **this concept was produced as a result of the sonic cruiser project**

Market Positioning



The 787-3 short-range version is the same length and height but with a shorter wingspan. The range is reduced to 6,480km

Japanese Order



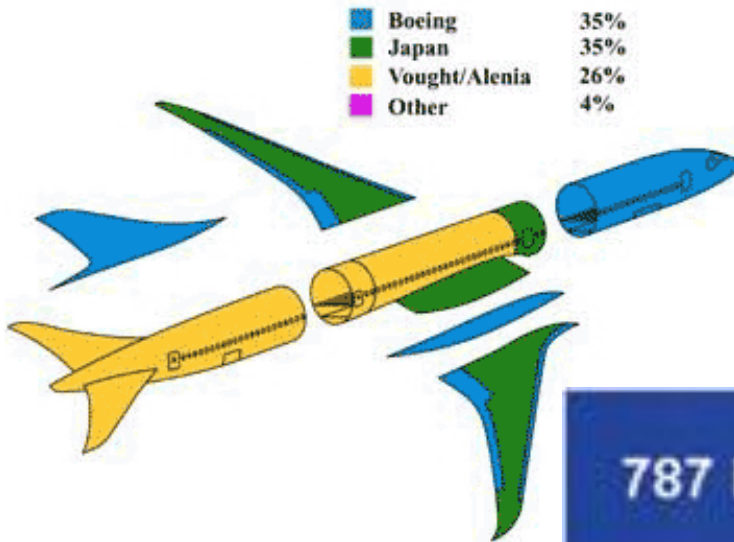
The launch order for 50 off 787 Dreamliner aircraft was placed by All Nippon Airways (ANA) and announced in April 2004

Orders for 850 Dreamliners

- The aircraft was originally scheduled to make its first flight in the summer of 2007, with delivery to airlines by early 2008, but the first test flight took place December 15th - 2009
- With the economic downturn hitting business in the travel industry, airlines cancelled their orders for 45 Dreamliners
- Nevertheless Boeing have said that it still has orders for more than 850 planes.

Supply Chain & Construction

7E7 Structures Work Share



787 Major Structure Partners



This manufacturing strategy acquires advanced manufacturing technology and helps to secure international orders for the plane

Supply Chain - Dreamlifter Transporters



Large 787 assemblies are transported to the final assembly site on board modified 747-400s rather than by traditional shipping methods, saving time and money.

Supply Chain – Fuselage Delivery



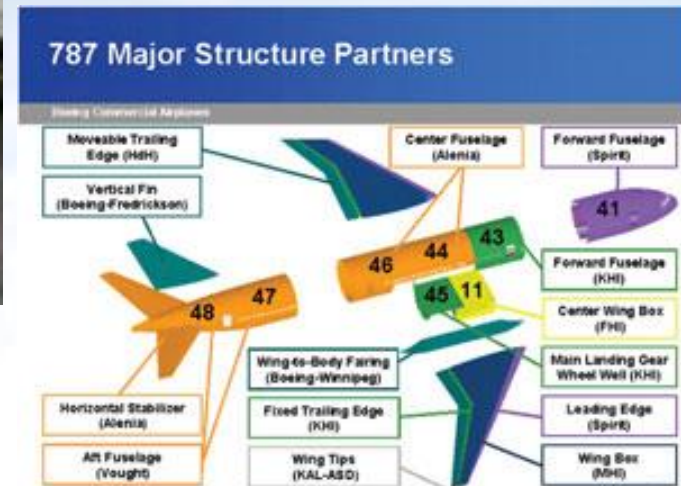
Fuselage Barrel
Sections are flown
into Boeing's
Everett Facility on a
Dreamlifter

Carbon Fibre Fuselage Fabrication



Automated tape laying machine linked into offline programming software

The last pressurized section of the fuselage, section 47 is produced by Vought Aircraft Industries using specially developed fibre placement technology.



Supply Chain



EVERETT, Wash., May 15, 2007 -- The composite wings for the Boeing 787 Dreamliner are delivered to Everett

Manufactured by Mitsubishi Heavy Industries at its facility in Nagoya, Japan, each wing is 98 feet long.

Supply Chain - Horizontal Stabilizer Delivery



The 787's first horizontal stabilizer is delivered to Boeing in Seattle

Manufactured by Alenia Aeronautica at its facility in Foggia, Italy, the stabilizer is transported in five pieces, the left and right stabilizer, two elevators and a center section.

Final Assembly



Final assembly of the all-new Boeing 787 Dreamliner - 2006

Assembly



Assembly of Section 41 of a 787 Dreamliner

Interior Design



Boeing has explored radical new concepts for the interior cabin configuration including 'sweeping arches' and 'a calming, simulated sky' to enhance passenger perception of spaciousness

Construction & Supply Chain

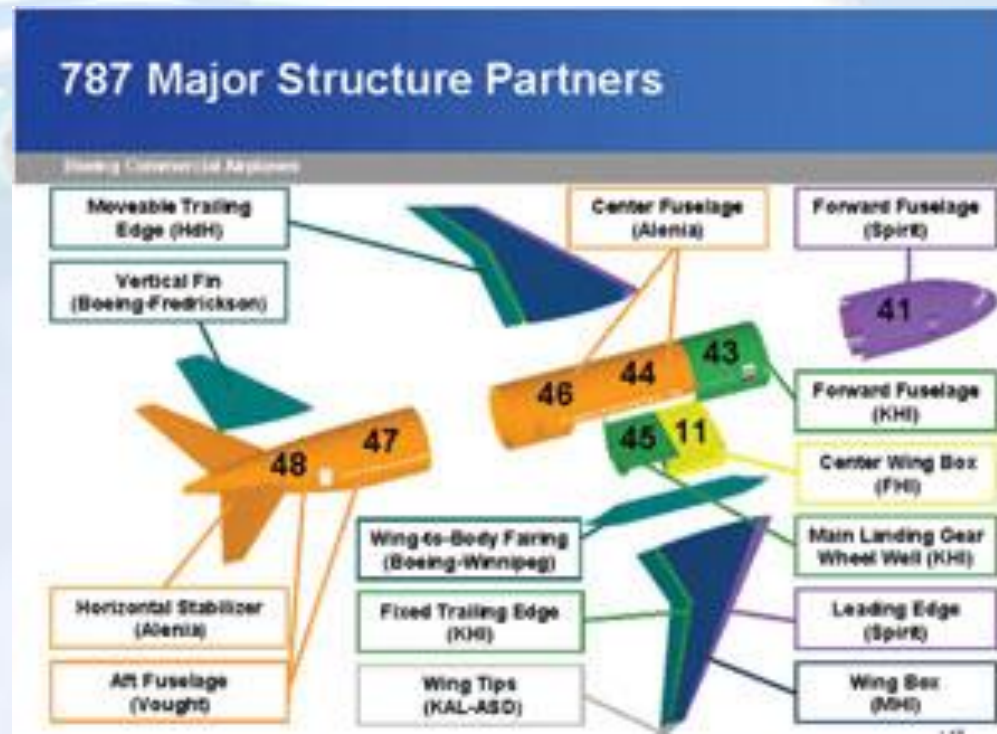
- The low sweptback wings have raked wingtips. Carbon fibre and epoxy composites and titanium graphite laminate is used in the construction of the wings
- The major structural work is being shared by principal industrial partners in USA, Japan and Europe.
- Boeing is responsible for about 33% of the production
- The flight deck and fuselage being manufactured at Wichita, the wings and the fuselage fairings at Winnipeg, Canada, the fin at Frederickson, and the moving leading and trailing edges of the wings at Tulsa and at Boeing Australia.

Supply Chain

- Japan's Fuji Heavy Industries manufacture the centre wing box and install the wells, 11 yellow
- Kawasaki Heavy Industries is responsible for the manufacture of the mid forward section of the fuselage, the fixed section of the wings and the landing gear well. 43, 45 green
- Mitsubishi Heavy Industries manufacture the wing box. Blue
- The all-composite nose section is built by Spirit Aerosystems of Wichita. 41 purple

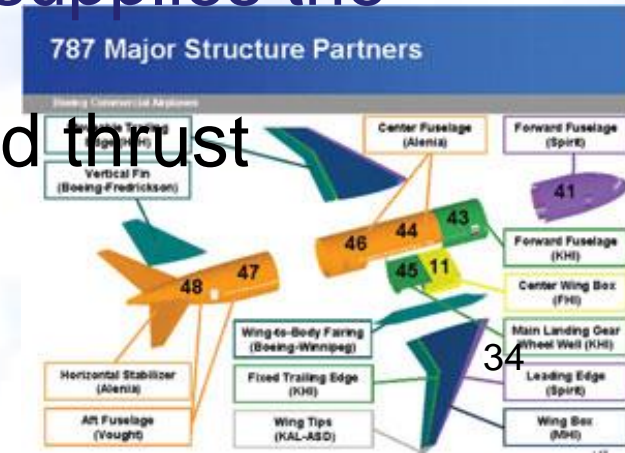
<https://www.youtube.com/watch?v=f07HpUAuVgk> Assembling the dreamliner

<https://www.youtube.com/watch?v=DVYaLwlgYgk> Full documentary



Supply Chain

- A joint venture company, Global Aeronautica, set up by Vought Aircraft Industries and Alenia Aeronautica, is responsible for the manufacture of the mid section and rear section of the fuselage including the tailplane, representing a 26% share of production which is based at Charleston, South Carolina. 44, 46, 47, 48 orange
- The French company Latecoere supplies the passenger doors.
- Goodrich provide the nacelles and thrust reverser



Supply Chain - Composite Fuselage

- The 787's all-composite fuselage makes it the first composite airliner in production.
- While the Boeing 777 contains 50% aluminum and 12% composites
- The 787 contains 15% aluminum, 50% composite (mostly carbon fiber reinforced plastic) and 12% titanium.
- Each fuselage barrel is manufactured in one piece, and the barrel sections joined end to end to form the fuselage.
- This eliminates the need for about 50,000 fasteners used in conventional airplane building.
- According to the manufacturer the composite is also more durable, allowing a higher cabin pressure during flight compared to aluminum.

Dis-assembled Fuselage Section



Supply Chain - Engines

- The aircraft is powered by high-bypass 10:1 ratio, extremely quiet engines.
- The fuel efficiency of the engines will contribute up to 8% of the increased efficiency of the aircraft.
- Boeing has selected two engine types:
 - General Electric GENX and
 - Rolls-Royce Trent 1000,
- Each developing 55,000lb to 70,000lb thrust.

Engine Pods have Chevron Edges to reduce noise



The 787 underwent extensive computer modeling and wind tunnel tests.



Supply Chain - Landing Gear

- Messier-Dowty of Velizy, France, supplies the main and nose landing gear.
- Smiths Aerospace provide the landing gear actuation systems
- Boeing have endured supply chain misery

Airbus A350 Competitor

Image of the new Airbus A350



The wing structure and fuselage will be made of carbon fibre composite

Boeing 787 Dreamliner

Boeing completed all flight tests required for type certification of the 787-8 Dreamliner with Rolls-Royce engines on Saturday, Aug. 13, 2011. The 787 flew its first commercial long-haul flight on January 21, 2012 from Haneda to Frankfurt on All Nippon Airways.



<http://www.youtube.com/watch?v=9yRmwGMNuDo&feature=youtu.be>

The A350 XWB (extra-wide bodied) project consists of three planes capable of carrying 270-350 passengers



The A350-800 will carry 250 passengers up to 8,800nm/16,300km – 89 orders. The A350-900, will accommodate as many as 300 passengers up to 7,500nm/13,900km – 473 orders. The A350-1000 will carry 350 to 440 up to passengers up to 8,400nm /15,600km – 163 orders. Total 725 Orders 30/10/2013

25 per cent step-change in fuel efficiency compared to its current long-range competitor.

Airbus brings together the very latest in aerodynamics, design and advanced technologies in the A350 XWB to provide a 25 per cent step-change in fuel efficiency compared to its current long-range competitor. Contributing to this performance are the Rolls-Royce Trent XWB engines that power the A350 XWB family.

Over 70 per cent of the A350 XWB's weight-efficient airframe is made from advanced materials, combining 53 per cent of composite structures with titanium and advanced aluminum alloys. The aircraft's innovative all-new Carbon Fibre Reinforced Plastic (CFRP) fuselage results in lower fuel consumption, as well as easier maintenance.

First test flight June 14th 2013. First delivery December 2014

A350 Competing on Interiors



Mood creation using ceiling projections.



Airbus ordered six MAG fibre placement machines for A350 fuselage – Sept 2008



Airbus and European partners previously purchased 14 MAG Cincinnati composite systems — four VIPER AFP machines and 10 automated tape layers (ATLs) — to produce parts for A320, A330, A340, A380 and A400M aircraft

A large Airbus A380 wing section is being assembled in a factory. The wing is suspended by yellow cranes and features a green and blue checkered pattern on its upper surface. The background shows the blue structural beams of the factory.

© AIRBUS S.A.S. 2012 - photo by e'm company / H. GOUSSE

A350 XWB fuselage barrel



Airbus starts production of first fuselage barrel for the A350 XWB (7 December 2010).

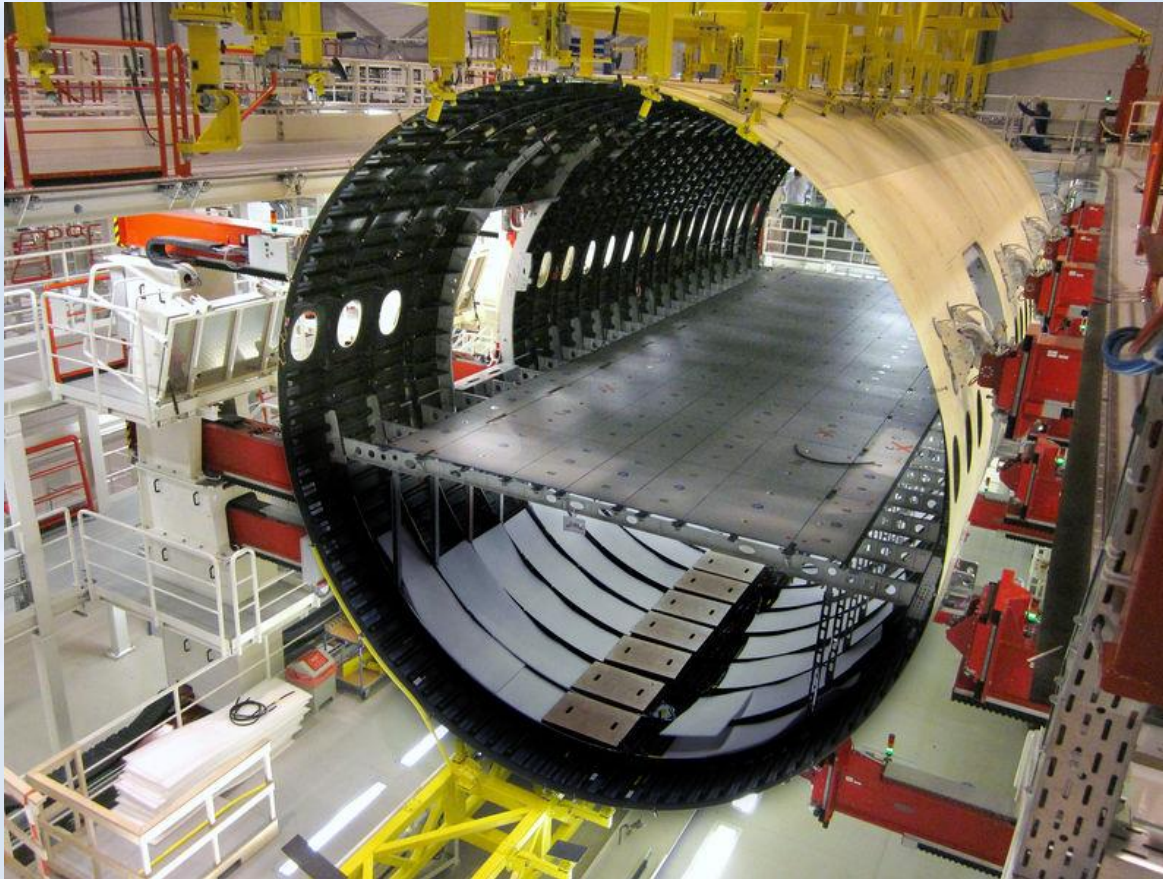
A350 Crown Panel - Skin Lay-Up



Longest A350 XWB carbon fibre fuselage panel manufactured. The curing of the first panel of the longest section of the A350 XWB's carbon fibre fuselage is manufactured by Spirit AeroSystems in Kinston, North Carolina (USA).

The 19.7 metre long, 77 square metre centre fuselage crown panel will undergo trimming, drilling and non-destructive inspection

A350 forward fuselage



Airbus partner
Premium Aerotec
manufactured the first
A350 XWB forward
fuselage in
Nordenham, Germany
(30 September 2011)

A350 wing shell lay-up 2010



Manufacture of the
A350 XWB lower
wing shells August
2010 at Illescas in
Spain (14
Septembre 2010)

A350 XWB Final Assembly Line VTP



The first flyable A350 XWB's vertical tail plane is shown at the A350 XWB Final Assembly Line on the day of this facility's inauguration. 23 Oct 2012

<https://www.youtube.com/watch?v=W0jlu0ghNlg> Final Assembly simulation

<https://www.youtube.com/watch?v=ofsUDBn4yXM> Actual Assembly

A350 XWB Flying test bed HG 1



The enhanced Trent XWB will deliver up to 97,000 lb. of thrust on takeoff, making it the most powerful engine ever developed for an Airbus aircraft.



Installation of the first Rolls-Royce Trent XWB flight-test engine on the A380 “flying-testbed” aircraft Airbus’ Jean-Luc Lagardère site in Toulouse (18 October 2011)

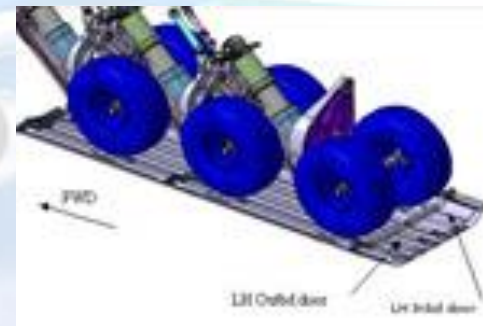
Composites Technology Research Malaysia



A320 spoilers



Moveable fairing



Airbus A400M
main landing door

CTRM is a single source and the largest composites component supplier for the Airbus A320 Series Aircraft Wing, covering 20% of the wing surface

An increasing number of parts are made from composite materials



Composites Technology Research Malaysia are very active in this area

56

Eurofighter Typhoon - a source of manufacturing technology



Eurofighter Typhoon



Typhoon Aircraft Structure

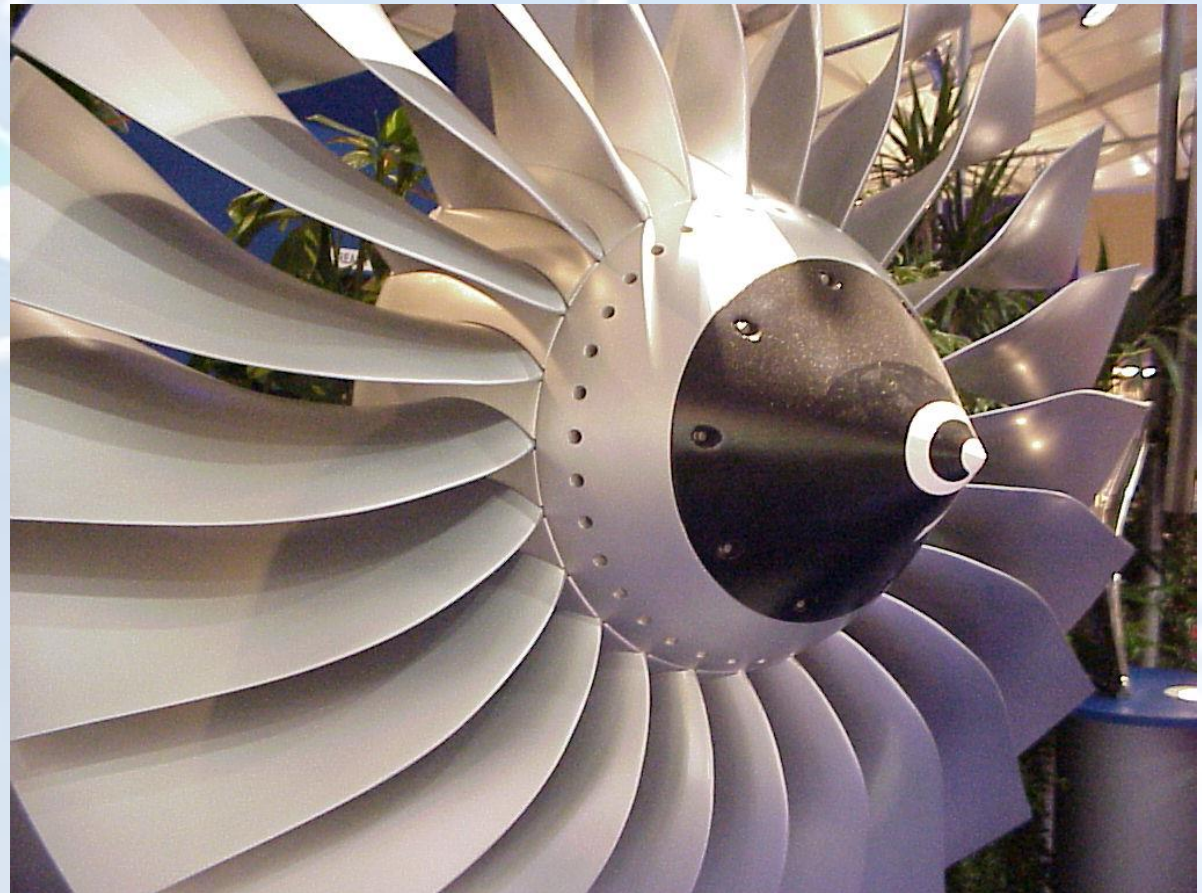
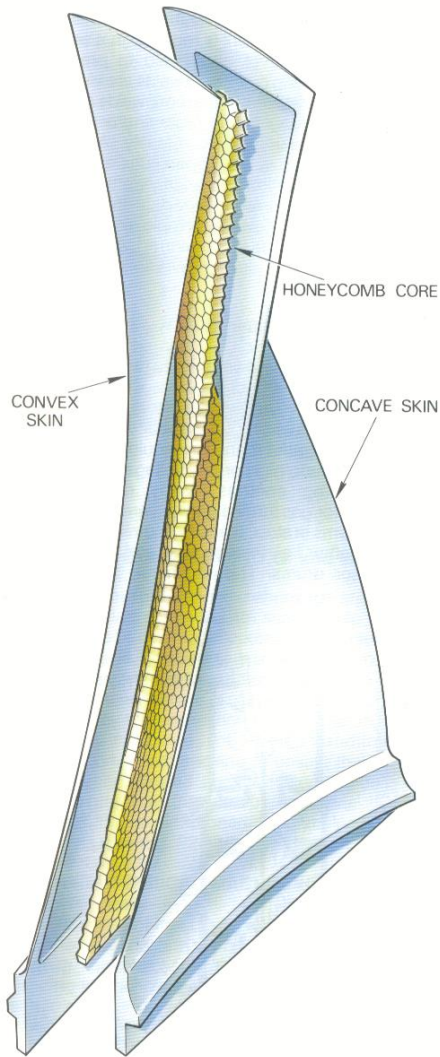
- In addition to new materials, new reliable and efficient methods for fabricating and bonding them, such as Super Plastic Forming, Diffusion Bonded (SPFDB) Titanium have been developed.
- Most of the aircraft shell, **>70%** is comprised of **Carbon Fibre Composite (CFC)**, namely; the outer fuselage, wings (including in-board flaperons) and rudder.
- Additionally a significant proportion of the structural members are also constructed from CFC.

Typhoon Aircraft Structure

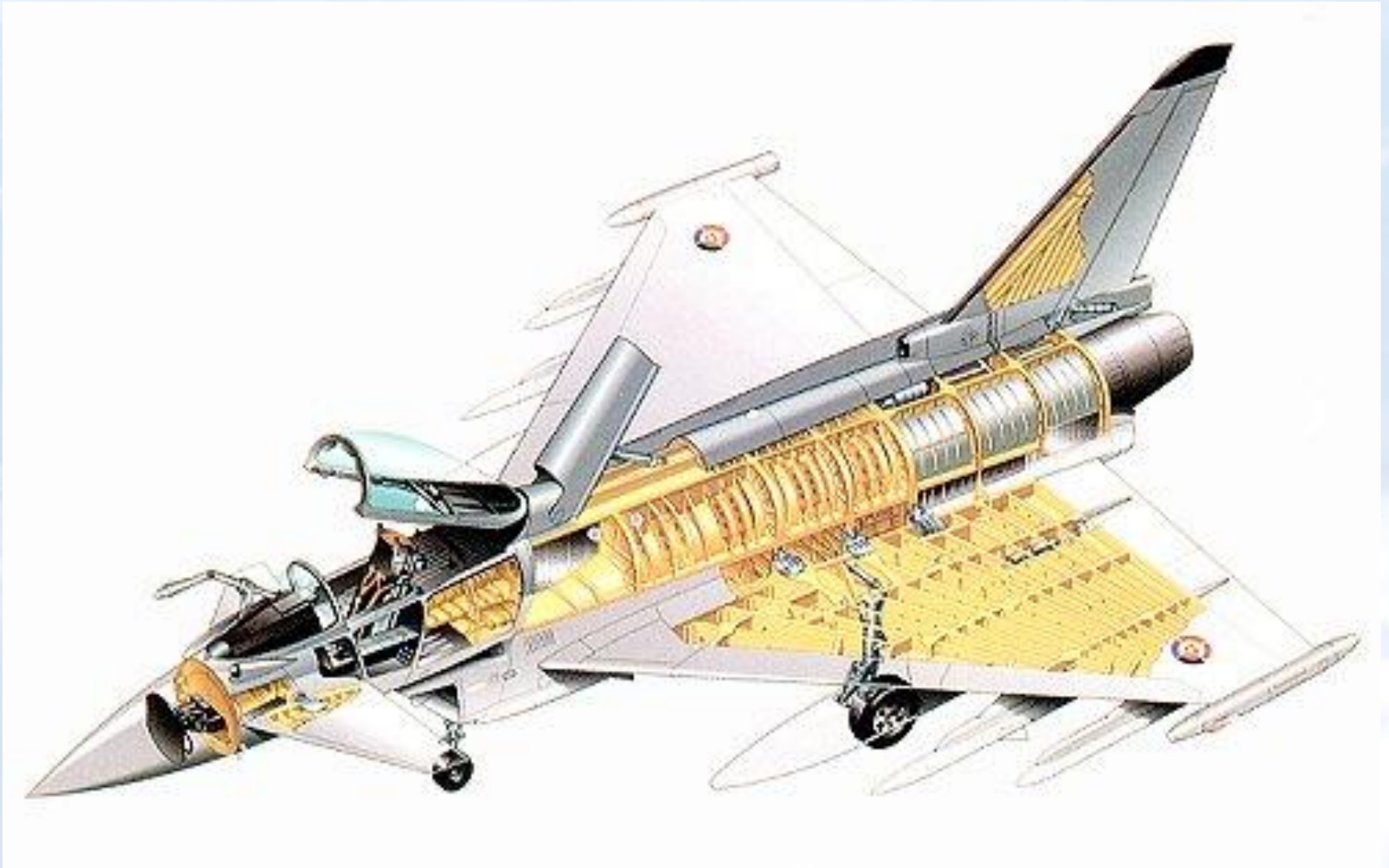
- Overall only **15%** of the Eurofighter shell is metal while **40%** of the structural weight comprises CFC
- The canards, out-board flaperons and engine nozzles are subject to large stresses and/or high temperatures and thus are made from SPFDB Titanium.
- The SPFDB process yields a far more rigid structure resulting in an improved strength to weight ratio compared to normal, machined Titanium.

Rolls Royce Bybass Fan Blade

Super Plastic Forming, Diffusion Bonded
(SPFDB - US patent 5,024,369) Titanium
Fan Blade.



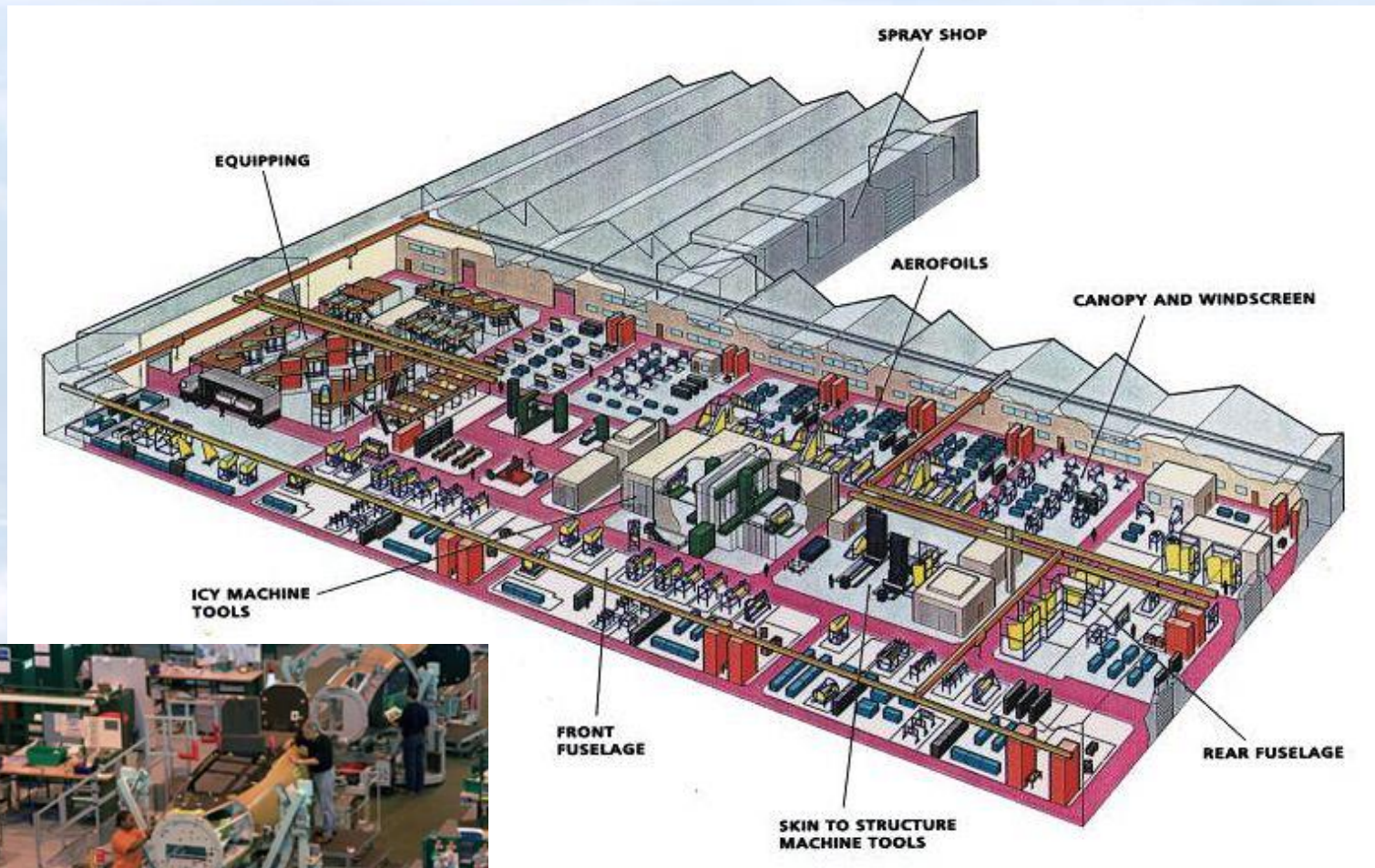
Eurofighter Typhoon, aircraft shell, >70% CFC



Eurofighter Typhoon



Samlesbury JIT Production Facility - BAE Systems



Samlesbury Production Facility - BAE Systems

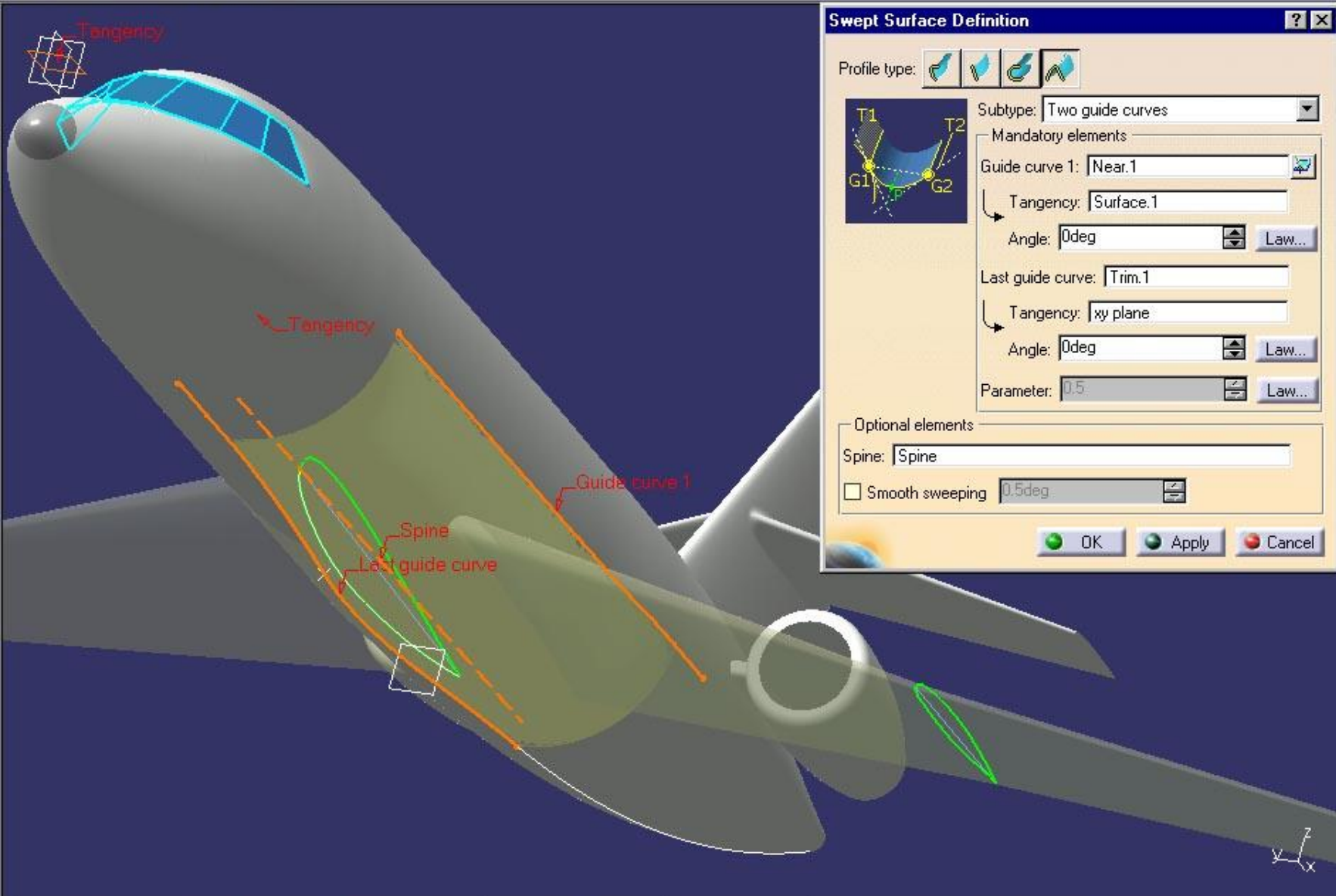
- Production equipment includes four **Advanced Contouring Machines (ACM)**, two five-axis machining centres (**FAM**), an **advanced 10-axis, gantry-type V4 Contour Tape Laying (CTL) machine**.
- The levels of production accuracy required are very demanding, panels and fittings have tolerances equal to 70 microns.
- This means that parts taken from one aircraft will fit any another, without modification.

V4 Contour Tape Laying (CTL)

- The V4 (version-4) CTL from Cincinnati Machine is being used to automate the production of the composite structures.
- The core purpose of the CTL is to automatically heat and lay the thermosetting composite *tape* over a pre-defined shape or *tool*.
- The machine is able to cope with both flat and contoured (or combinations of both) tools enabling the complex curves and edges of various Eurofighter parts to be followed precisely.

V4 Contour Tape Laying (CTL)

- The CTL even automates the moving and positioning of tools for subsequent lay-up of the composite material.
- To support high lay-up speeds and *large part capability* the version-4 CTL provides 12.8 m X-axis longitudinal travel and 4.2 m Y-axis traverse.
- It is equipped with 635mm diameter reels providing 800 to 900 m of tape.
- The CTL technology improves quality and reduces production times, when compared to older manual lay-up methods.



Swept Surface Definition

Profile type:

Subtype: Two guide curves

Mandatory elements

Guide curve 1: Near.1

Tangency: Surface.1

Angle: 0deg Law...

Last guide curve: Trim.1

Tangency: xy plane

Angle: 0deg Law...

Parameter: 0.5 Law...

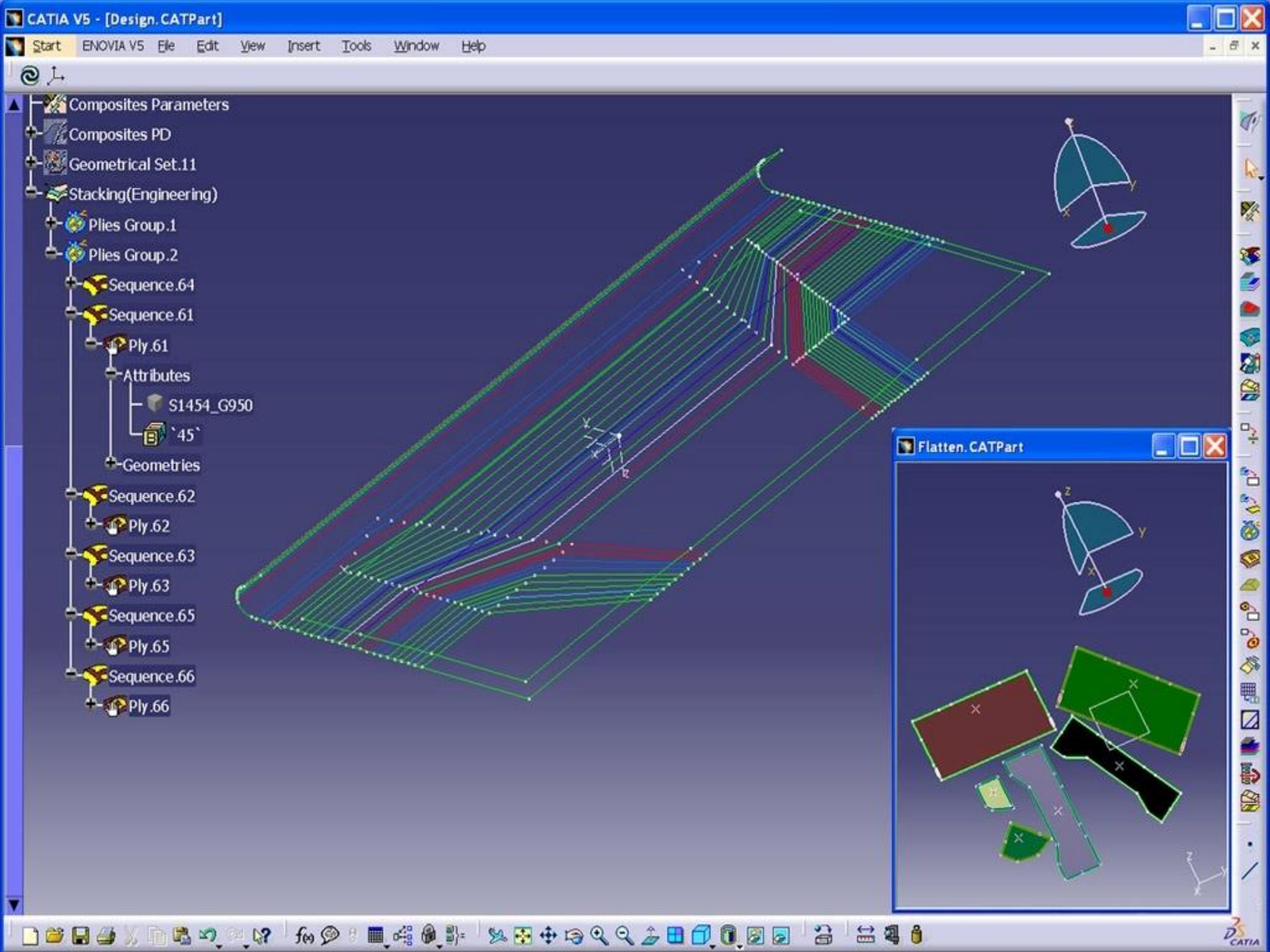
Optional elements

Spine: Spine

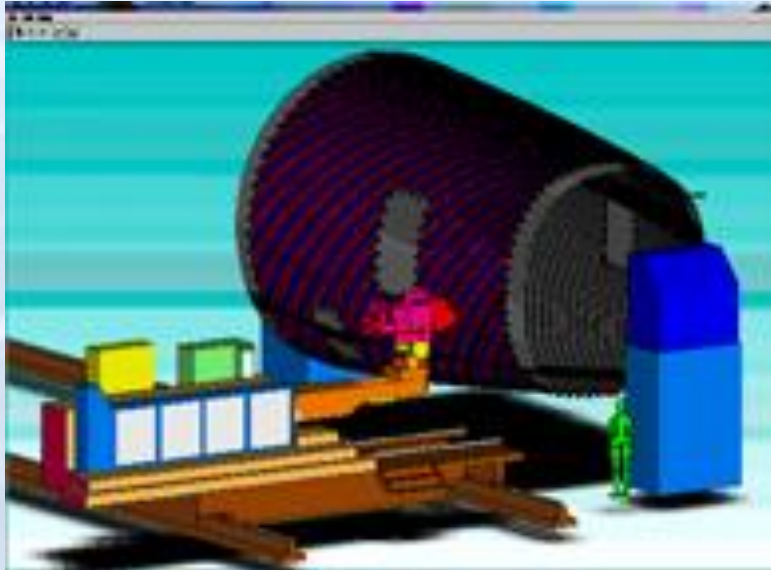
☐ Smooth sweeping 0.5deg

OK Apply Cancel





Offline - Analysis, Simulation & Programming Tools for Tape Laying and Fiber Placement



ACES software: *Supports numerous processes*

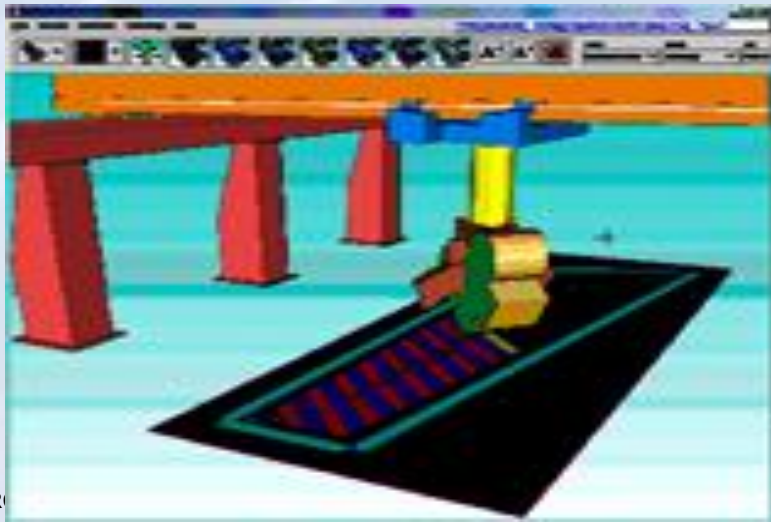
- Tape Laying, Fiber Placement and Hybrid
- Models all material widths
- Wide range of path types

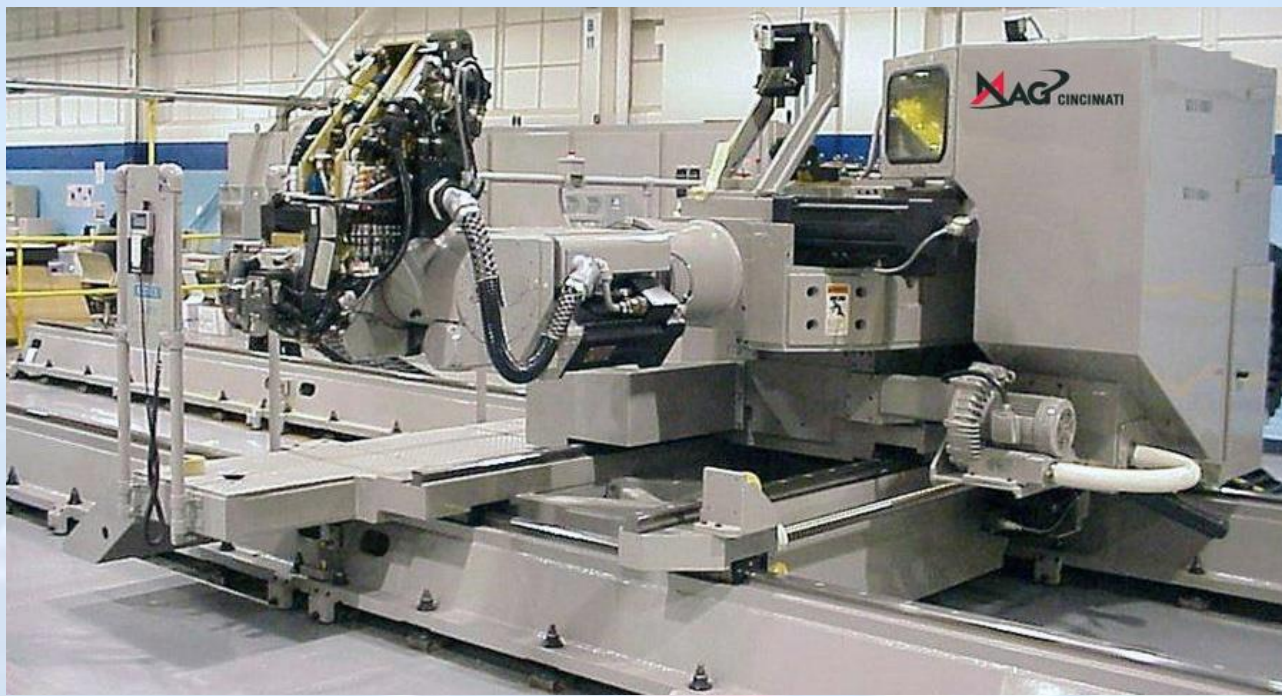
Producibility Analysis

- Evaluates process capability
- Highlights process limits
- Collision avoidance and machine travel

Productivity Analysis

- Cycle time and material usage





VIPER Fiber Placement Systems

combine the advantages of tape laying and filament winding with advanced computer control and software.

With 7 axes of motion, the machines are particularly suited to highly contoured structures such as: cowl, ducts, fuselage sections, pressure tanks, nozzle cones, tapered casings, fan blades, spars and "C" channels.



VIPER Fiber Placement Systems

MAG's VIPER® Fiber Placement Systems automatically and independently control up to 32 individual tows or slit tape producing a variable bandwidth "on-the-fly".

Each tow can be independently dispensed, clamped, cut and restarted during fiber placement. Gaps and overlaps are minimized as the machine precisely lays interior or exterior contoured boundaries.

The VIPER's advanced design delivers other key advantages to automated production including maintaining constant angle on a complex surface, in-process compaction of material and no limits to ply orientations.

Below : building a component; computer simulation of build and off line programming

<http://www.youtube.com/watch?v=xK4gMDduHgA&list=PL8C19F00482CD476F>

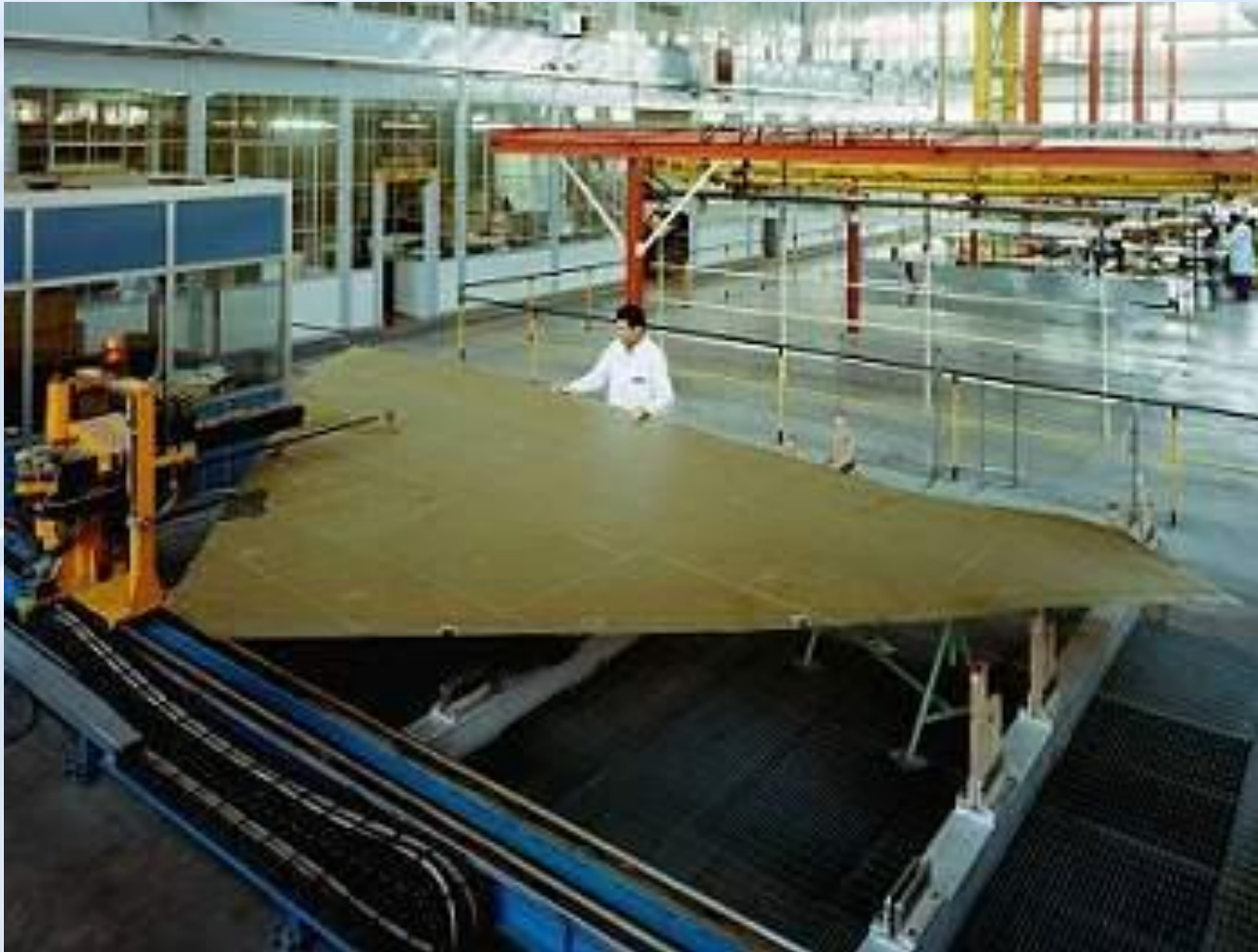
<https://www.youtube.com/watch?v=RX43s8-0cR4&list=PLzJWimmWdnHyAAP4qGGGpSZ918c8-J81b> Simulation tape laying

<https://www.youtube.com/watch?v=QDbrVTWnFIU&list=PLzJWimmWdnHyAAP4qGGGpSZ918c8-J81b> Ingersoll tape laying

Wing Manufacture

- Foggia is home to Alenia's manufacturing base for the left wing of the Typhoon.
- Alenia has two High Contour Tape Laying (HCTL) Cincinnati Machines.
- As with the CTLs at Samlesbury the machines are used for the production of composite sections of the left wing.
- These particular CTLs are provided with new high-contour heads which increase clearance around the tape laying head itself by 60%.
- This enables the machine to better handle more highly-contoured, angular shapes.

High Contour Tape Laying (HCTL) Cincinnati Machines



Conclusions or Lessons

- Manufacture with composites is being automated to improve:
 - Speed of manufacture
 - Quality & accuracy
 - Component interchangeably
- CAD design & manufacturing software is constantly improving
- Defence projects can provide a rich source of advanced manufacturing technology and design ideas
- Sometimes it is difficult to mix defence and commercial contracts

Conclusions or Lessons

- The Dreamliner is a bold step in aerospace design
- A larger reduction of travel time seems to be possible by using direct point to point services, instead of hub and spoke connections (reason for dropping sonic cruiser)
- Acquire advanced manufacturing technology and design by using the supply chain
- By sharing out the work internationally you guarantee international orders

Conclusions or Lessons

- Be sure that you can enforce JIT delivery throughout your supply chain
- Be sure that you can control suppliers' quality effectively
- Sometimes it is better to follow than to lead, hence the A350 arrived in 2013 and already had 490 orders
- It seems Airbus is learning from Boeings mistakes
- A350 October 2015 - 787 orders; 10 deliveries
- Boeing 787 October 2015 – 1124 orders; 340 deliveries

Laminating



Trimming and Painting



Autoclave



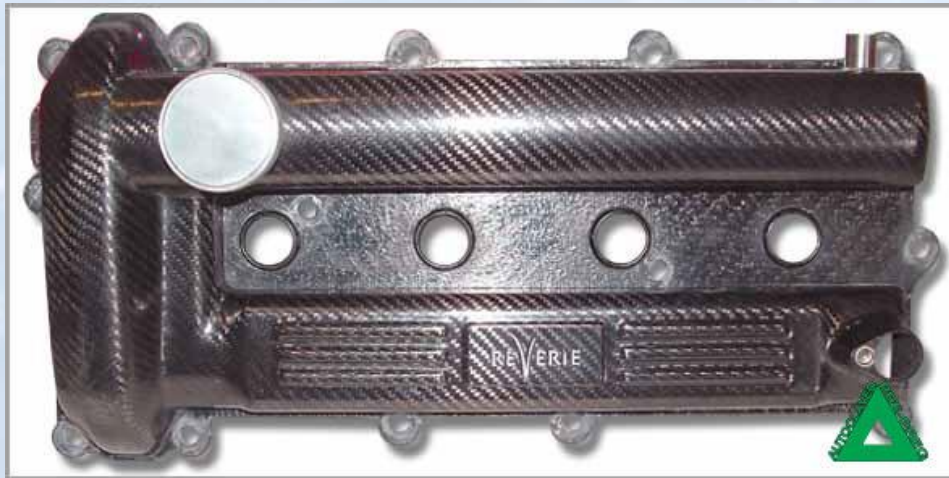
- An autoclave is effectively a pressurised oven allowing the curing of parts at up to 120PSI to ensure excellent consolidation of the finished part.



Aston Martin Rear Diffuser



Engine Cam Cover



YB Cosworth Turbo Heatshield



FIA Tested Steering Wheel



2011 McLaren MP4-12C

<http://cars.mclaren.com/production>

<http://cars.mclaren.com/design>



<http://www.mclarenautomotive.com/uk/p11/explode/default.aspx#/p11/explode/>

Lotus Elise



Rear Diffuser



S2 Elise/Exige 111r & 240r (inc Wheel Arches, Rear Wings, Side Scoops, Induction Systems, & Engine Covers)

Lotus Elise Rear Floor Section



Mulsanne C, Twin Skin Seat, Carbon Fibre



Daytona, Elise/Exige S2 111R & 240R/2-Eleven, Induction System





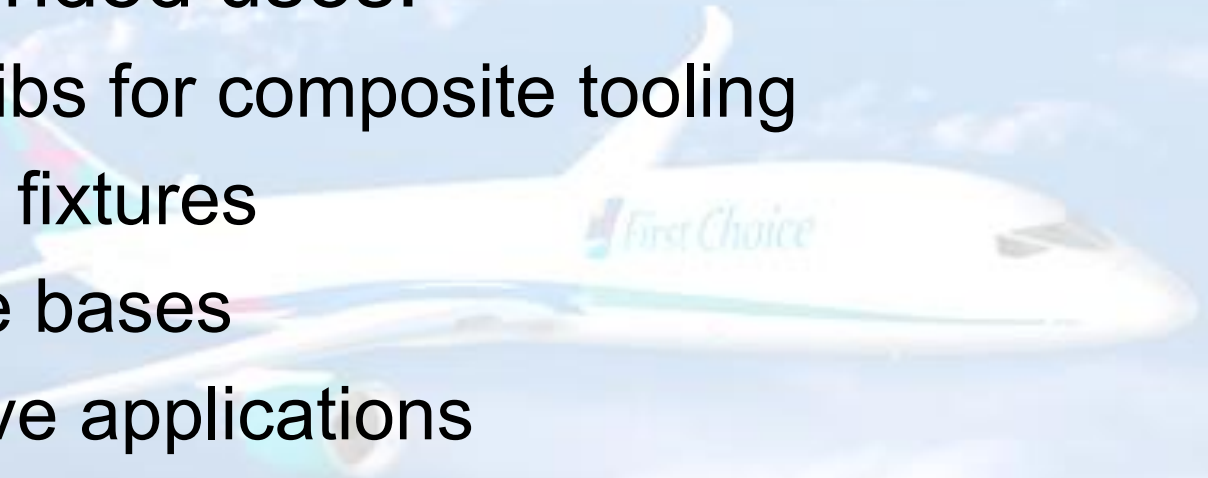
Carbon fibre SLS materials offer high performance end use properties make this material suitable for all motor sport applications, including Formula 1.

Sandwich Panels

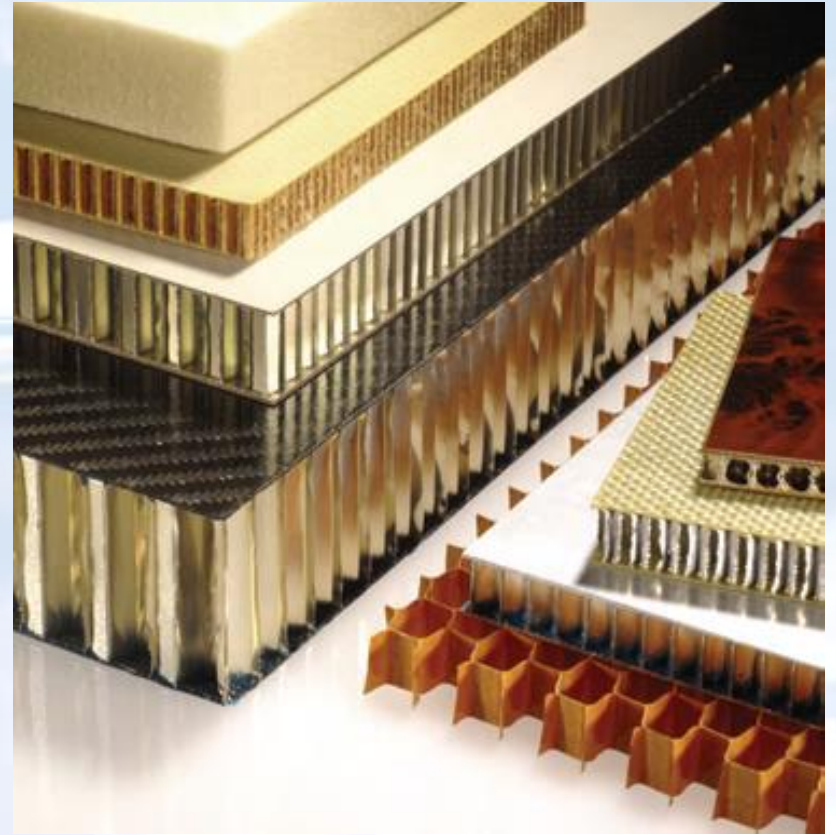
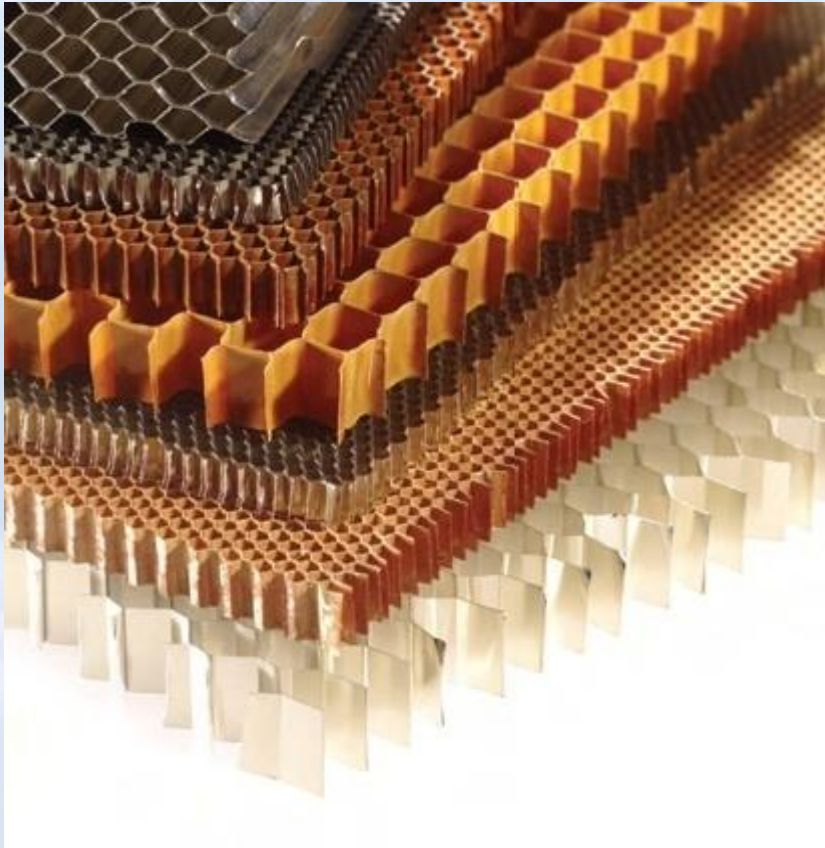
- The Cellite Sandwich Panel is based around a standard aluminium honeycomb core with aluminium, glass or carbon fibre skins and is available in three standard overall thicknesses.
- Bespoke panels with honeycomb (Aluminium or Nomex) or foam cores and skin configuration to meet specific performance requirements in whatever thickness are readily available.
- Amber Composites can offer guidance in the selection of materials to provide the optimum sandwich panel for your application

Sandwich Panel Uses

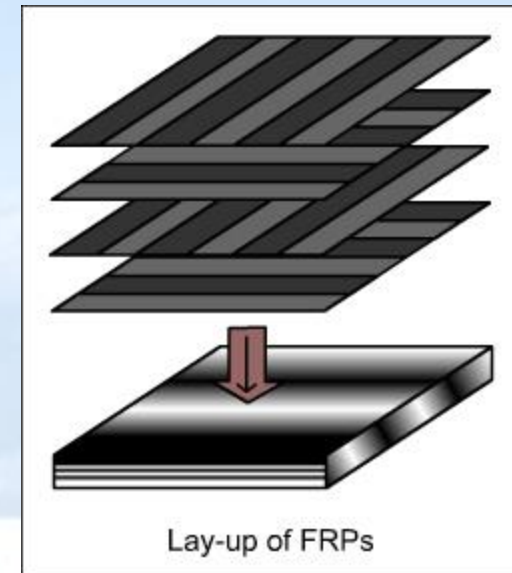
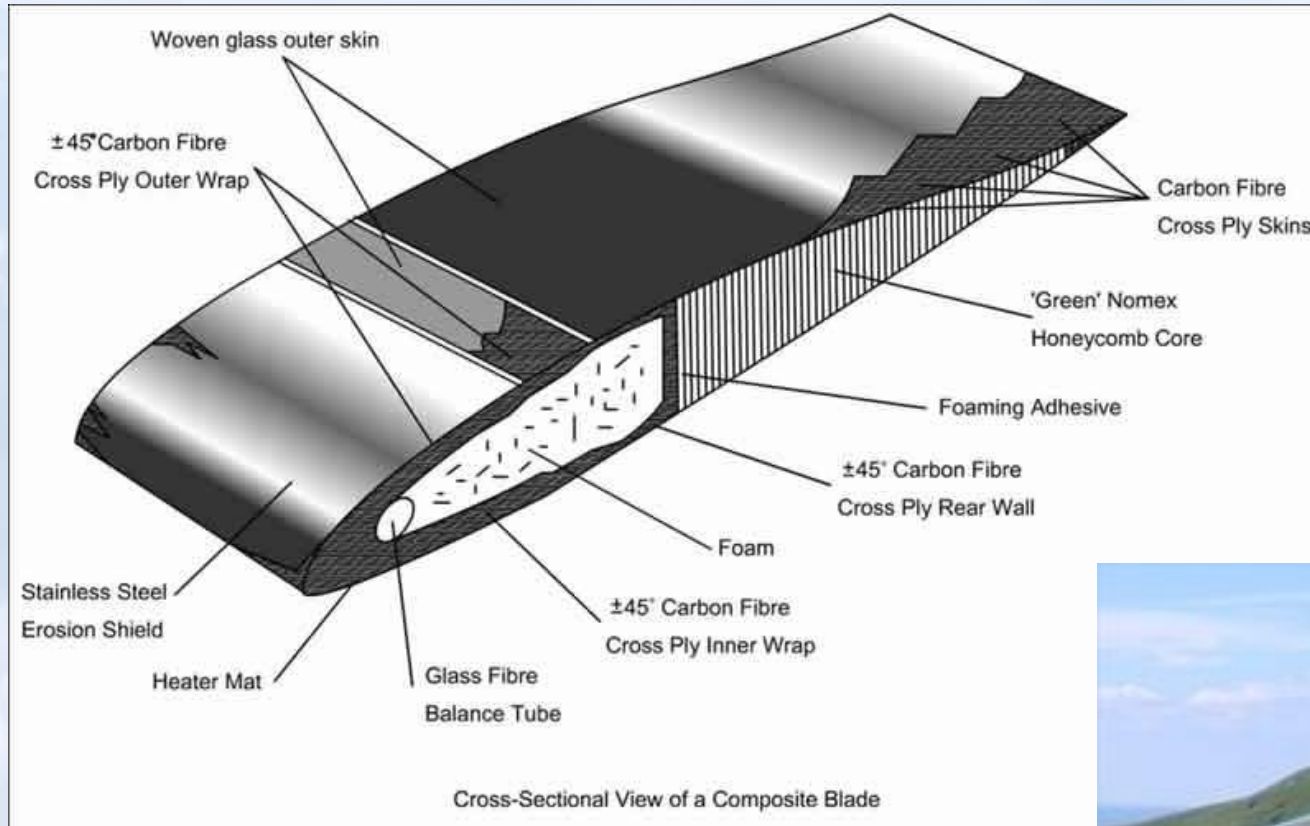
- Recommended uses:
 - Support ribs for composite tooling
 - Checking fixtures
 - Autoclave bases
 - Automotive applications
 - Precision based boards



Honeycomb Cores With Skins



Helicopter Rotors



Helicopter Blade materials

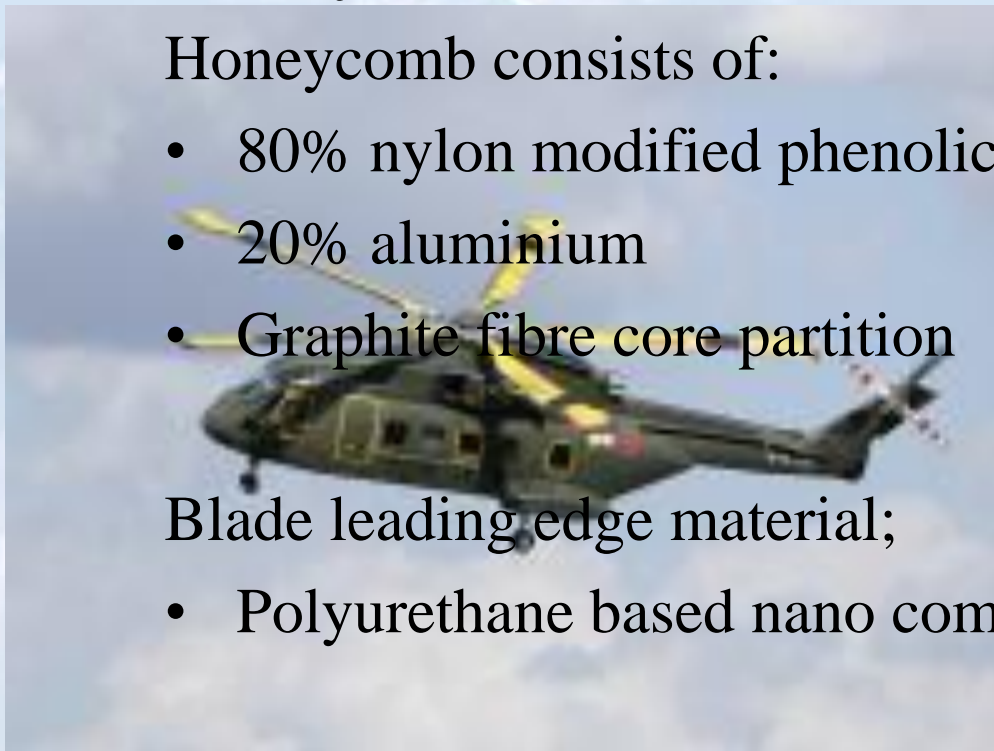
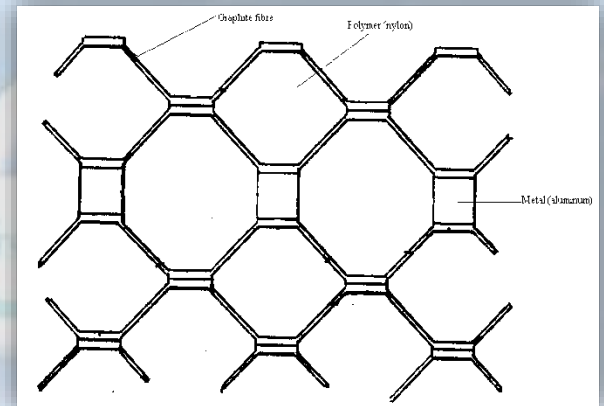
Glass fibre reinforced epoxy resin casing with honeycomb core.

Honeycomb consists of:

- 80% nylon modified phenolic resin
- 20% aluminium
- Graphite fibre core partition

Blade leading edge material;

- Polyurethane based nano composite



Formula 1 Monocoque Body shell



The Formula 1 safety record has increased greatly with this technology



The International Space Station uses composite panel technology



Processing of Polymer-Matrix-Reinforced Plastics

- High strength-to-weight and stiffness-to-weight ratios and creep resistance
- Substantial costs, not competitive with processing traditional materials and shapes at high production rates.
- Important environmental issues: dust generated during processing, airborne carbon fibres, etc

Processing of Polymer-Matrix-Reinforced Plastics

- Reinforcement may be: chopped fibres, woven fabric or mat, roving or yarn (slightly twisted fibre), or continuous lengths of fibre
- In order to obtain good bonding between the reinforcing fibres and the polymer matrix, as well as to protect the fibres during subsequent processing, the fibres are surface treated by impregnation (sizing)
- Short fibres are commonly added to thermoplastics for injection moulding; milled fibres can be used for reaction injection moulding, longer chopped fibres are used primarily in compression moulding of reinforced plastics

Processing of Polymer-Matrix-Reinforced Plastics

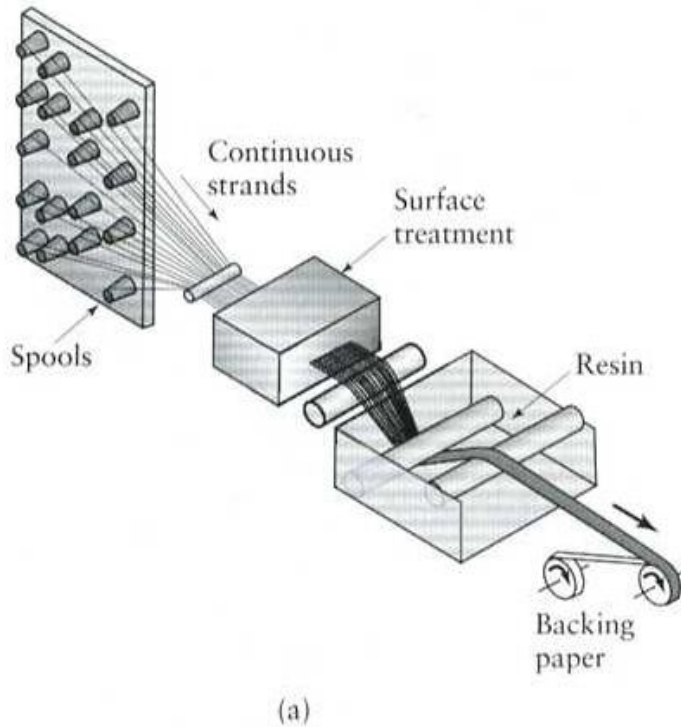
- When the impregnation is done as a separate step, the resulting partially cured sheet are referred to by various names
- Prepregs, Sheet-moulding compound (SMC), Bulk-moulding compound (BMC), Thick-moulding compound (TMC).
- Video below shows production of SMC

<https://www.youtube.com/watch?v=42Q6NbOpzSw> sheet moulding compounds

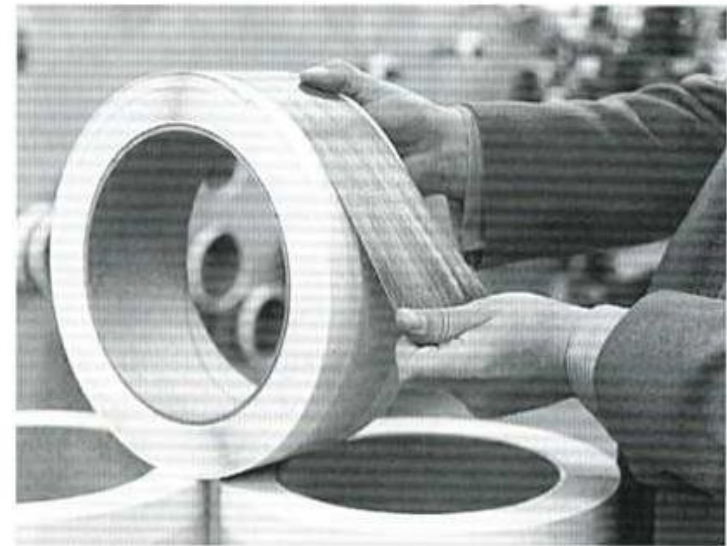
Processing of Polymer-Matrix-Reinforced Plastics

- Prepregs: See figure 1 (a) for manufacture of sheet or tape see figure 1 (b).
- Individual pieces of sheet are assembled into laminated structures. Special computer controlled tape laying machines have been developed for this purpose.
- Products include: Architectural panelling, panels for construction, electrical insulation, structural components for aircraft

Prepregs Fig 1



Manufacturing Process for
Polymer –Matrix Composite



Boron-Epoxy Prepreg Tape

Prepreg Manufacture



Carbon fibers are usually mixed with resin to form a "Pre-Preg" (Pre-impregnated) sheet, wound between release paper

A filming line used in the production of carbon fiber prepreg at SP Systems

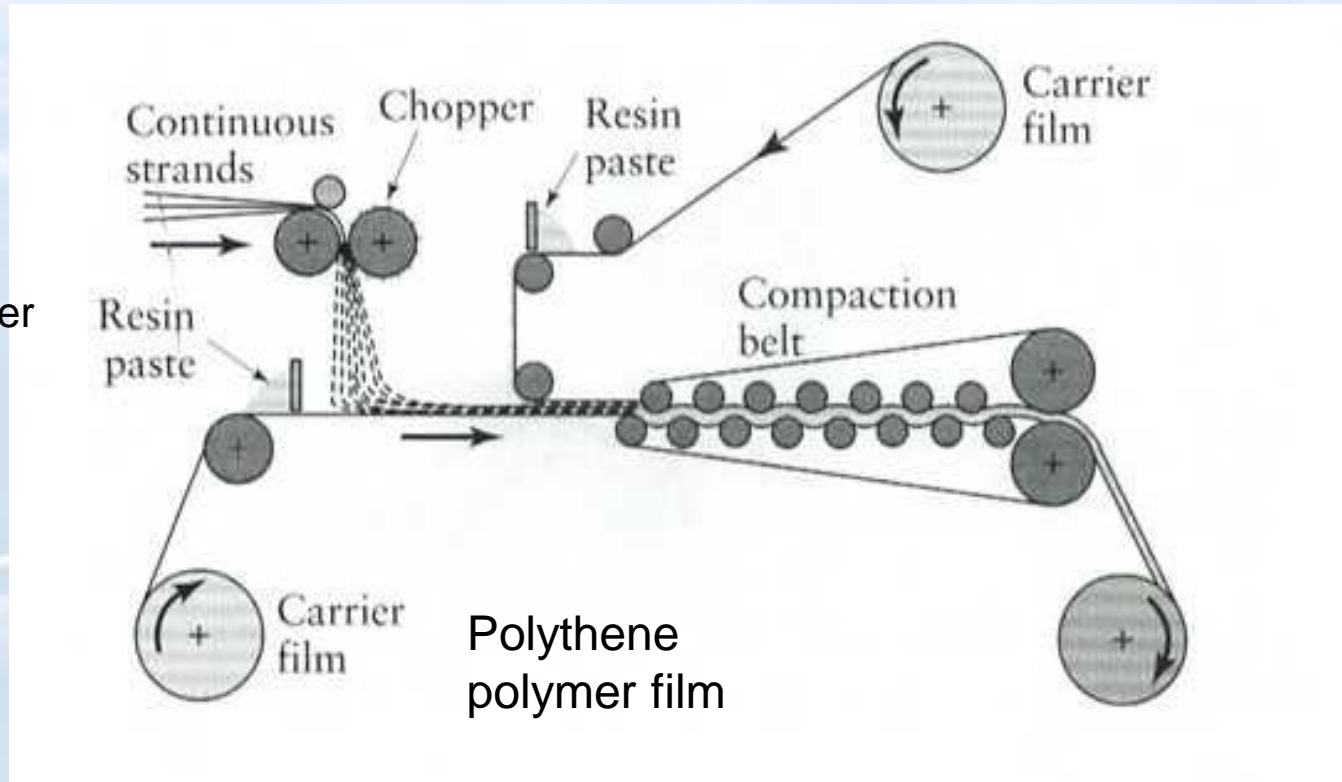
<https://www.youtube.com/watch?v=kaoq8Mc4xxw>

Processing of Polymer-Matrix-Reinforced Plastics

- Sheet-moulding compound, see figure 2
- Having being formed into a roll the product is stored until it undergoes a maturing process when it reaches the required viscosity. This takes one day at the correct temperature and humidity.
- The matured SMC has a leather like feel and is tack free, it has a shelf life of 30 days

Sheet Moulding Compound Fig 2

Usually polyester mixture



Manufacturing process for producing reinforced-plastic sheets. The sheet is still viscous at this stage and can later be shaped into various products

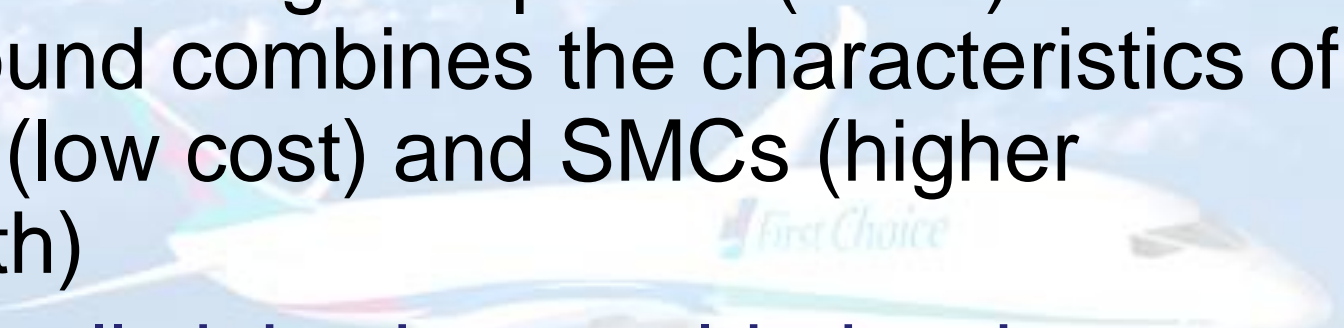
https://www.youtube.com/watch?v=aEb7DV71_T8

Processing of Polymer-Matrix-Reinforced Plastics

- Bulk-moulding compound: Supplied as billets, generally up to 50 mm diameter
- They are made in the same manner as SMCs, by extrusion
- When processed into products BMCs have flow characteristics similar to that of dough, hence they are called dough-moulding components (DMCs)

Processing of Polymer-Matrix-Reinforced Plastics

- Thick-moulding compound (TMC): The compound combines the characteristics of BMCs (low cost) and SMCs (higher strength)
- It is usually injection moulded, using chopped fibres of various lengths
- One of its applications is for electrical components, because of the high dielectric strength of TMCs



Tennis Rackets

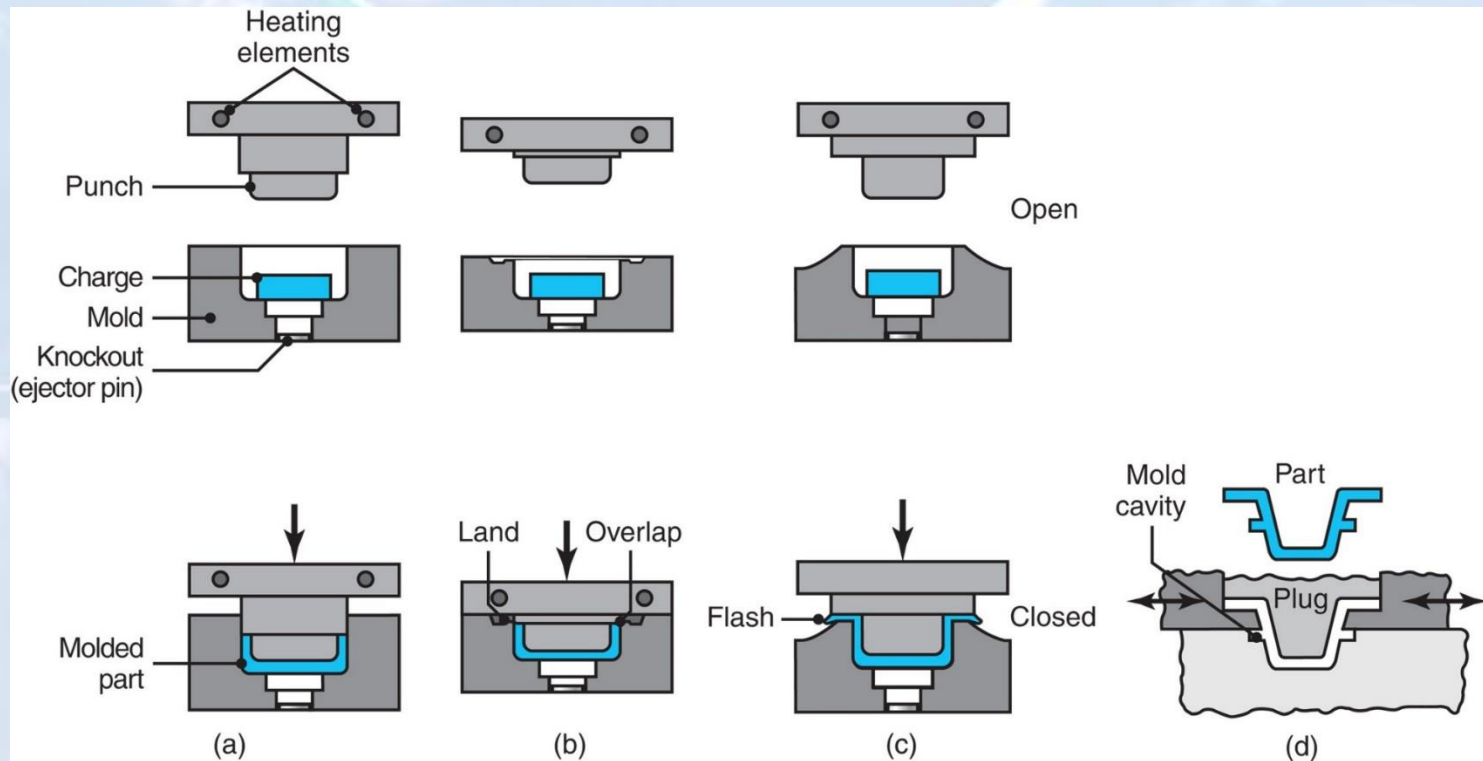
- Tennis rackets require light weight and stiffness
- Tennis rackets are being manufactured with graphite, fibreglass, boron, silicon carbide and Kevlar as reinforcing fibres
- Rackets have a foam core; some have unidirectional reinforcement others have braided reinforcement
- Rackets with boron fibres have the highest stiffness followed by graphite, glass and Kevlar fibres
- The racket with the lowest stiffness has 80% fibreglass, whereas the stiffest racket has 95% graphite and 5% boron fibres



Processing of Polymer-Matrix-Reinforced Plastics

- In Compression Moulding, the material is placed between two moulds and pressure is applied, the moulds may be heated to accelerate hardening
- The material may be BMC or SMC, fibre lengths generally range between 3 to 50mm

Types of compression molding, a process similar to forging: (a) positive; (b) semipositive; and (c) flash, in which the flash is later trimmed off. (d) Die design for making a compression-molded part with external undercuts.

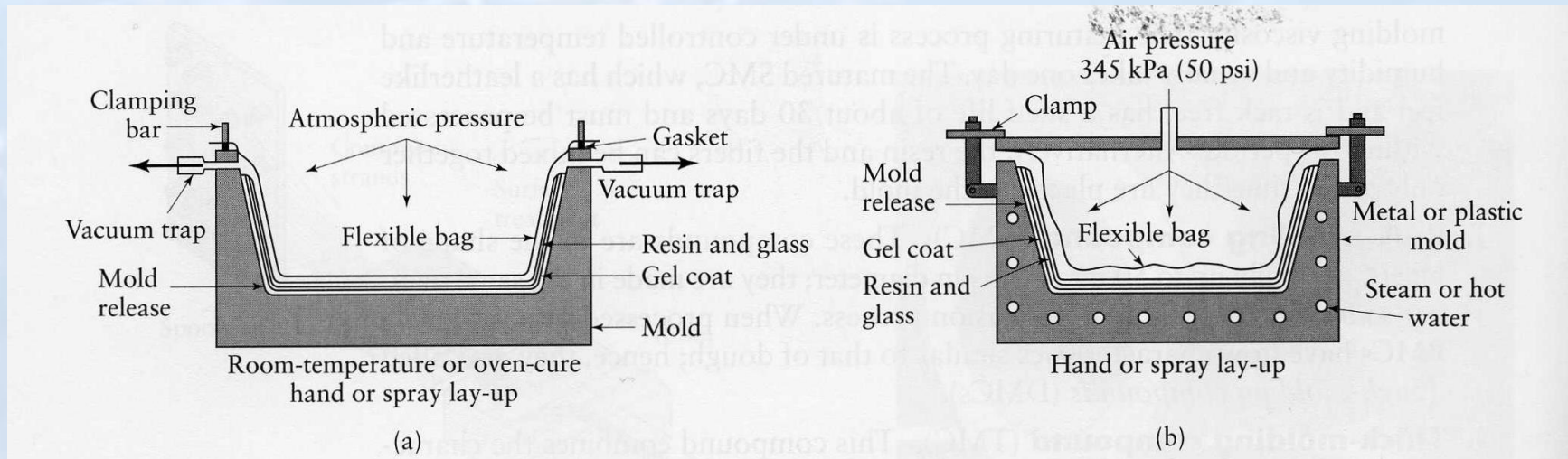


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Vacuum-bag moulding

- See Figure 3, prepregs are laid in a mould to form the desired shape
- The pressure required to form the shape and develop good bonding is obtained by covering the lay-up with a plastic bag and creating a vacuum
- If additional heat and pressure are desired, the entire assembly is put in an autoclave
- The moulds can be made of metal, usually aluminium, but more often are made from the same resin (with reinforcement) as the material to be cured; this eliminates problems related to differential thermal expansion

Moulding Reinforced Plastics Fig 3



(a) Vacuum-bag forming

(b) Pressure-bag forming

One:1



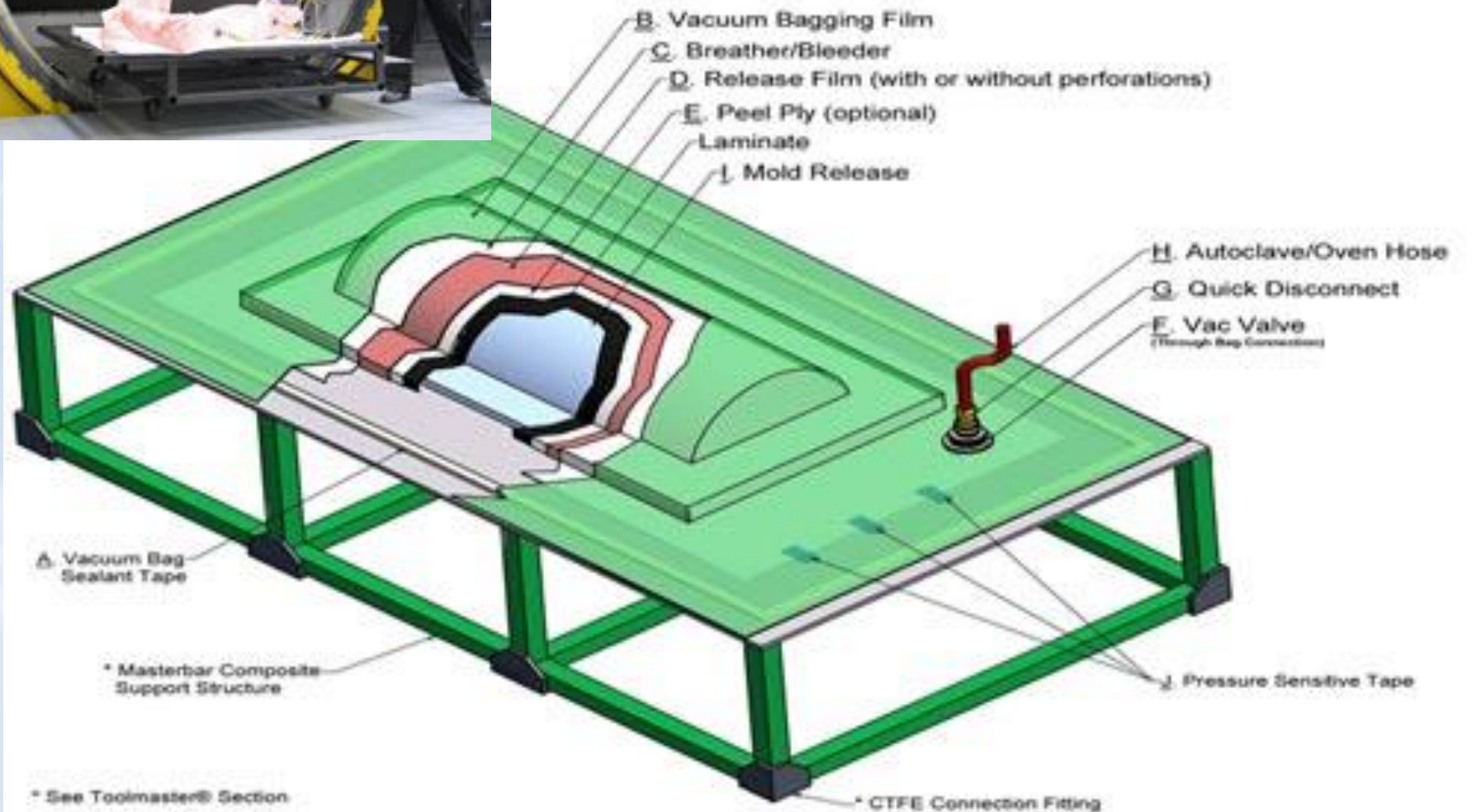
https://www.youtube.com/watch?v=504I_hJDFck inside Koenigsegg carbon fibre



<https://www.youtube.com/watch?v=cb9WBPzseYA> how its made



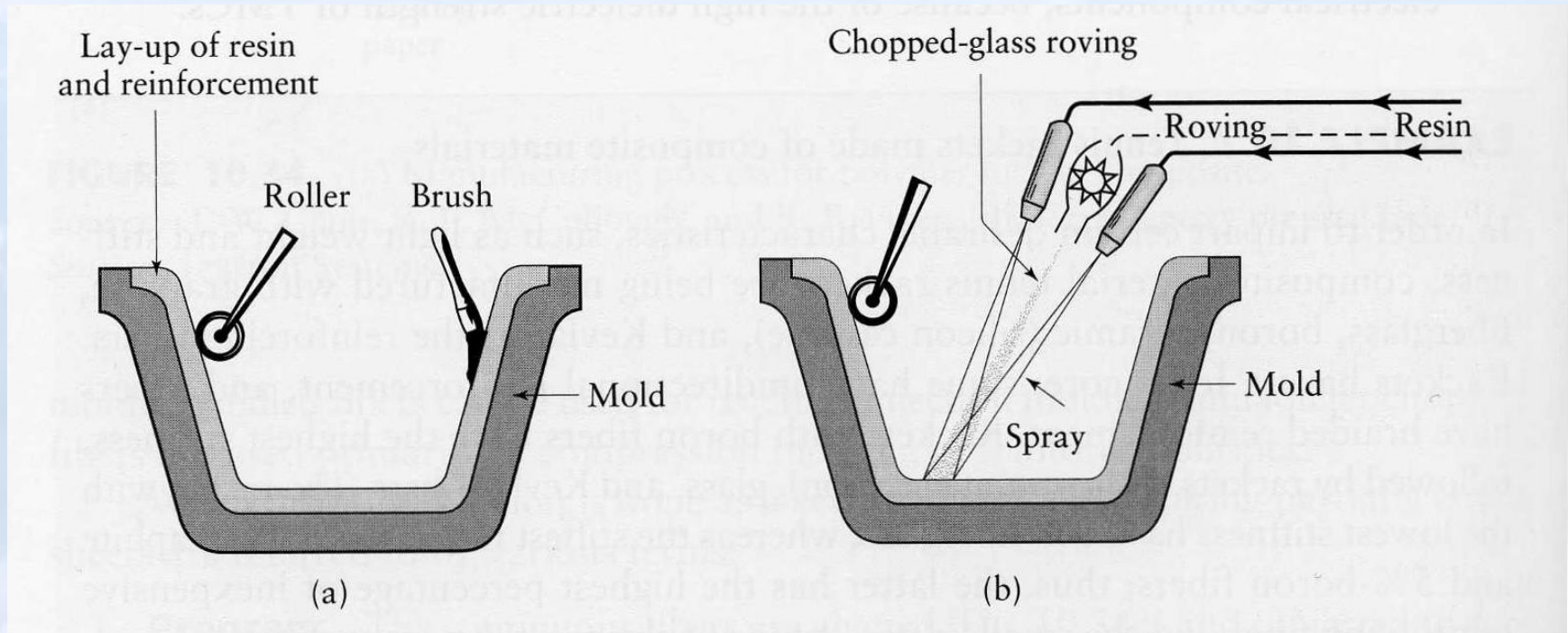
The moulding of pre-impregnated fabrics and film infused fabrics typically requires the use of elevated temperatures and vacuum consolidation under a vacuum bag in either Oven or Autoclave.



Contact Moulding

- Uses a male or female mould, see fig 4, made of materials such as reinforced plastics, wood or plaster.
- Contact moulding is used in making products with high surface-area-to-thickness ratios, such as swimming pools, boats, tub and shower units, and housings
- Although, via automation, spray-up increases the speed of production, the process is slow and labour costs are high

Moulding Reinforced Plastics Fig 4



Manual methods of processing reinforced plastics:

(a) Hand lay-up

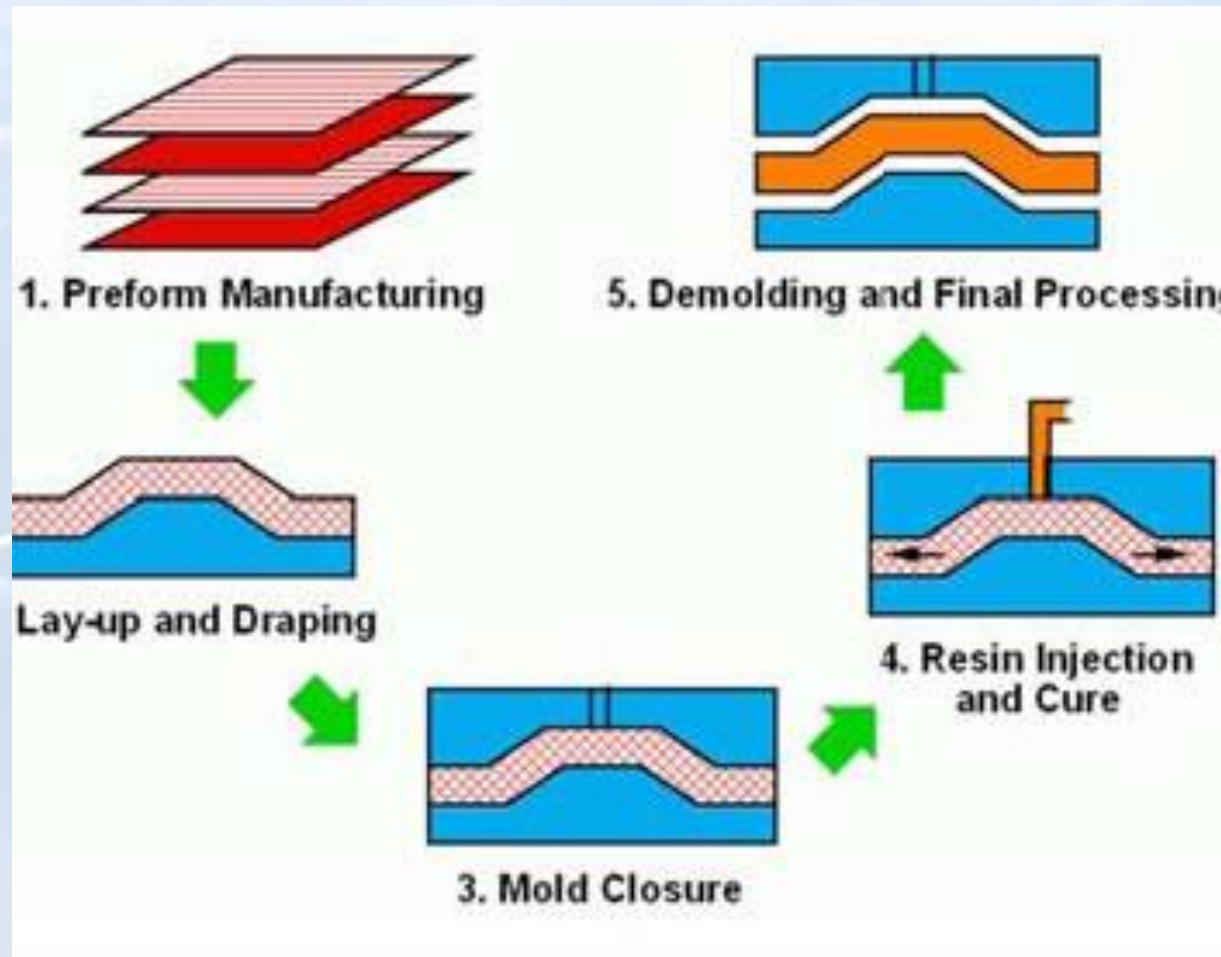
(b) Spray-up

These methods are also called open-mould processing

Resin Transfer Moulding

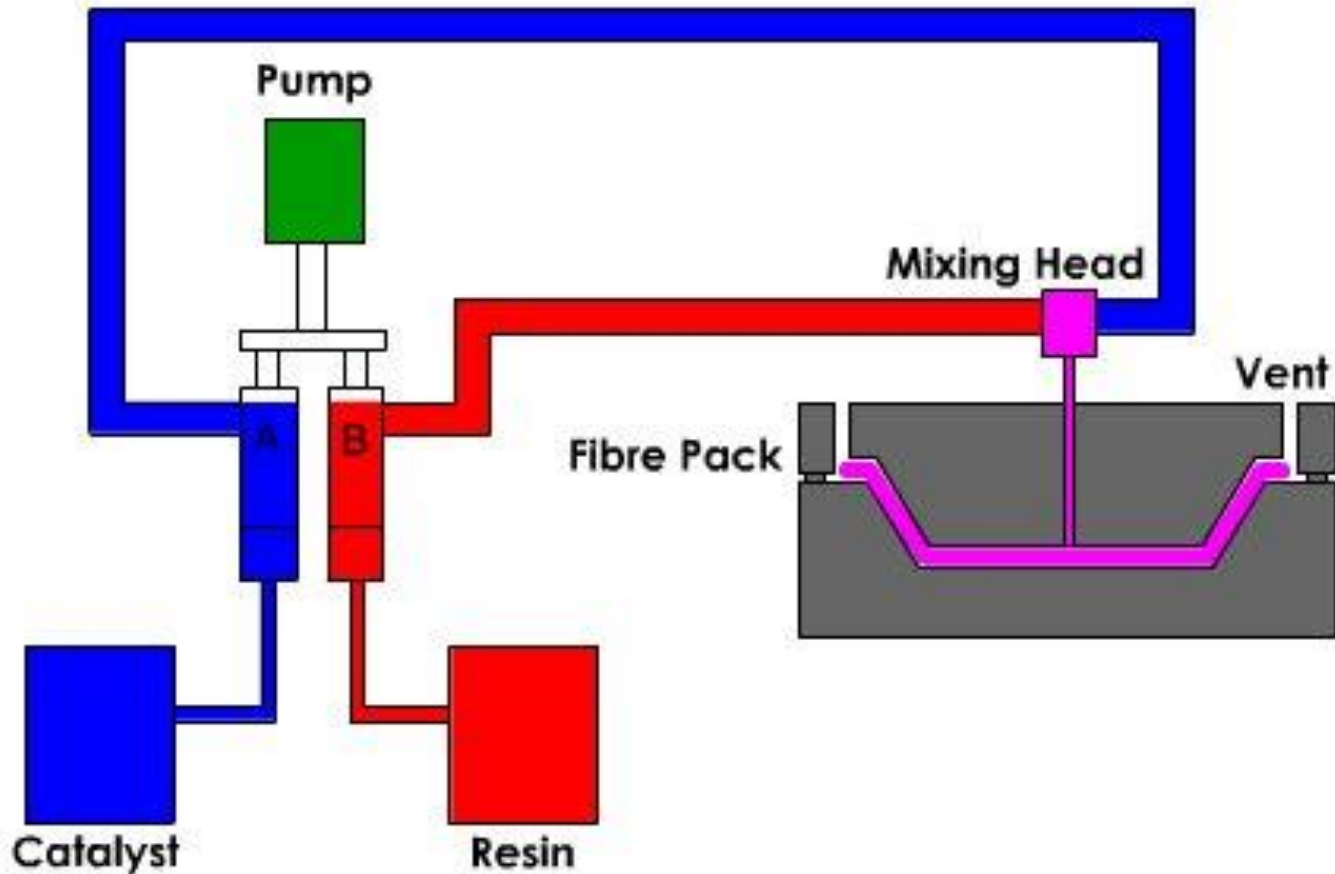
- A resin mixed with a catalyst is forced by a piston positive displacement pump into a mould cavity filled with fibre reinforcement.
- The process is a viable alternative to hand lay-up, spray-up and compression moulding for low or intermediate volume production

Resin Transfer Moulding



RTM

Resin Transfer Moulding (RTM)



<http://www.youtube.com/watch?v=1u-2GvhghQA>

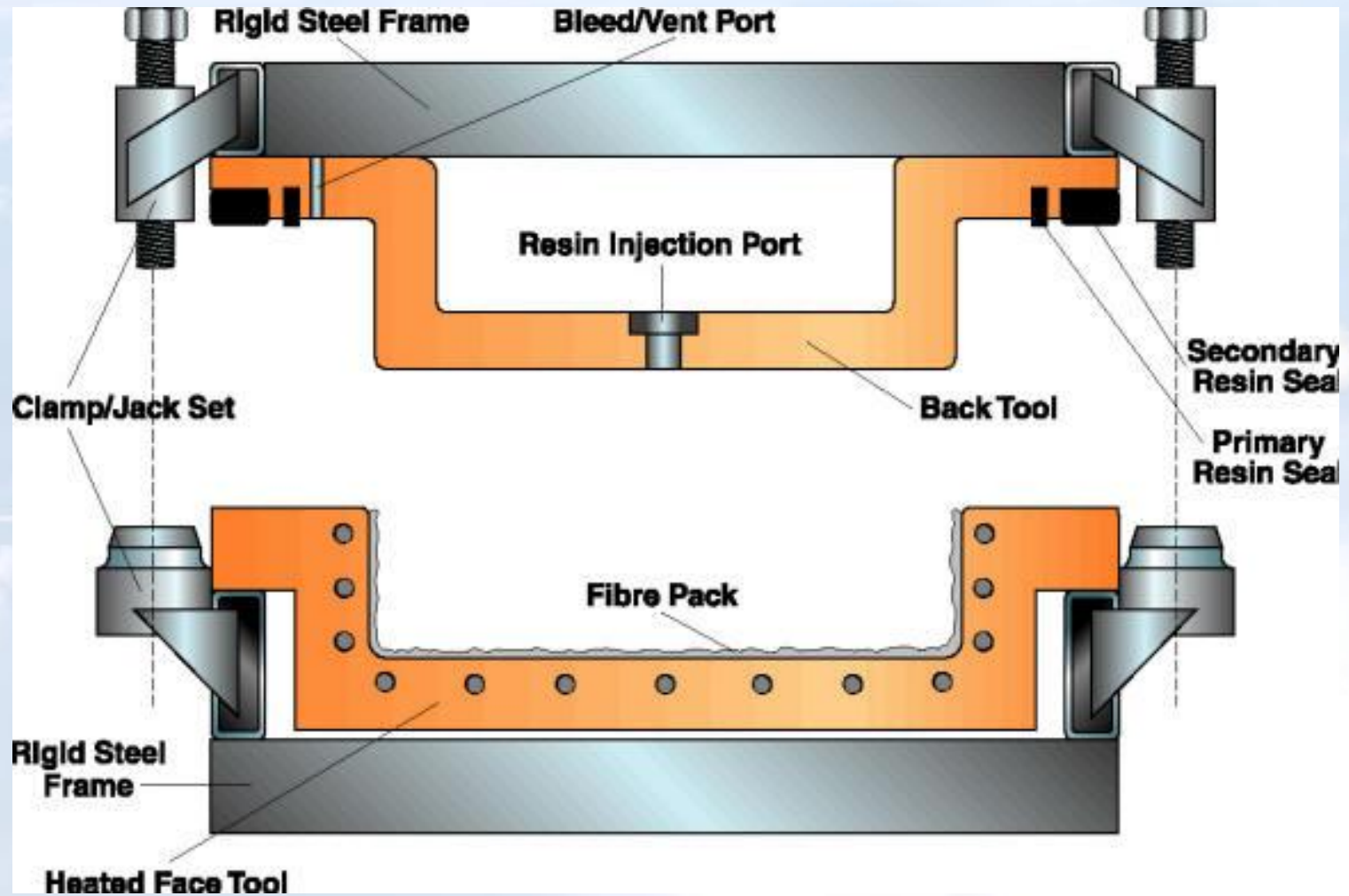
Vacuum Assisted RTM



Resin Transfer Moulding (RTM)

- RTM is a low pressure moulding process, where a mixed resin and catalyst are injected into a closed mould containing a fibre pack or preform. When the resin has cured the mould can be opened and the finished component removed.
- A wide range of resin systems can be used including polyester, vinylester, epoxy, phenolic and methyl methacrylates etc, combined with pigments and fillers including aluminium trihydrates and calcium carbonates.
- The fibre pack can be either, glass, carbon, arimid, or a combination of these. There are a large variety of weights and styles commonly available.

RTM



RTM

- **The Advantages and Benefits of using RTM:**
- Mouldings can be manufactured to close dimensional tolerances
- Components will have good surface finish on both sides
- Selective reinforcement and accurate fibre management is achievable
- Ability to build-in fibre volume fraction loadings up to 65%
- Uniformity of thickness and fibre loading, resulting in uniform shrinkage
- Inserts may be incorporated into mouldings
- Tooling costs comparatively low compared to other manufacturing processes
- Uses only low pressure injection
- Low volatile emission during processing
- Ability to produce near net shape mouldings, reducing material wastage
- Process can be automated, resulting in higher production rates with less scrap
- Ability to mould complex structural and hollow shapes
- Low resultant voidage in moulded components
- Ability to achieve from 0.5mm to 90mm laminate thickness

McLaren Sports Car

<https://www.youtube.com/watch?v=1u-2GvhghQA> Resin transfer moulding



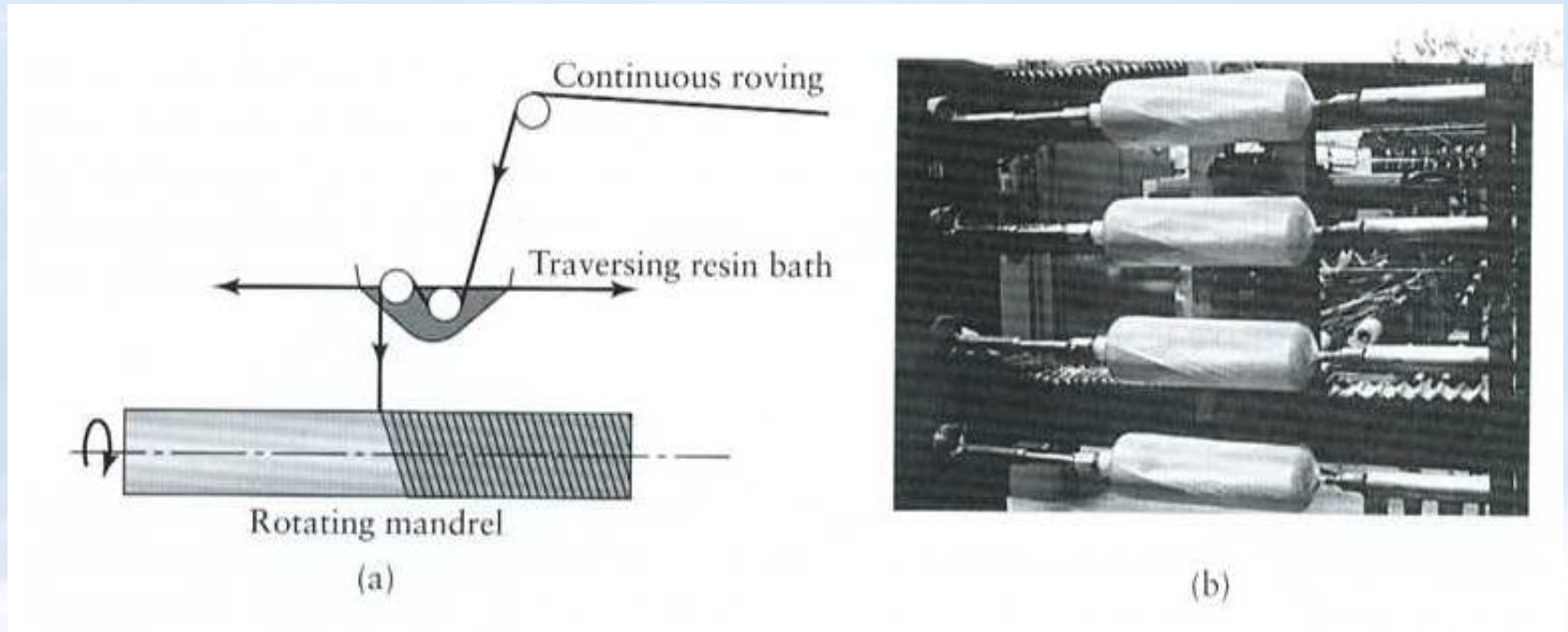
Transfer Injection Moulding

- Is an automated process that combines compression moulding, injection moulding and transfer moulding
- It combines the advantages of each process and produces parts with enhanced properties

Filament Winding

- Resin and fibres are combined at the time of curing. Axisymmetric parts, such as pipes and storage tanks, as well as asymmetric parts are produced on a rotating mandrel
- The reinforcements are impregnated by passing through a polymer bath, see Fig 5a
- This process can be modified by wrapping the mandrel with prepreg

Filament Winding Fig 5



(a) Filament winding process

(b) Fibre glass being wound over aluminium liners for slide-raft inflation vessels for the Boeing 767 aircraft

Filament Winding

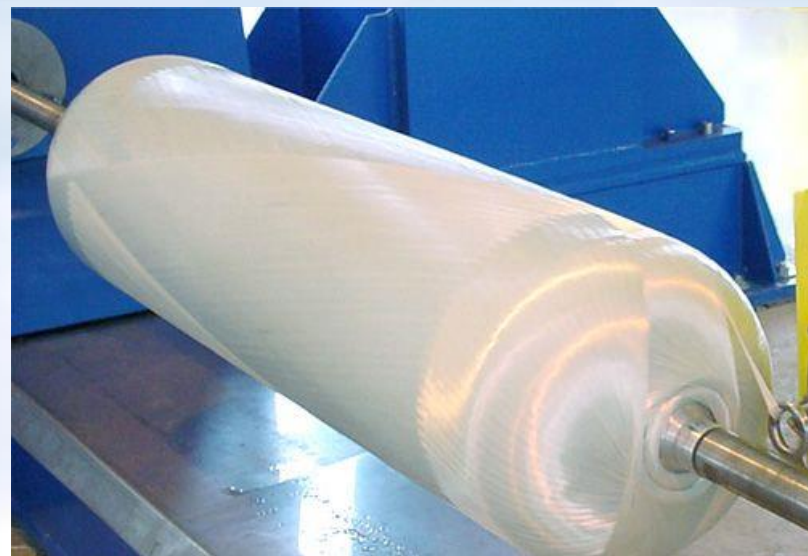
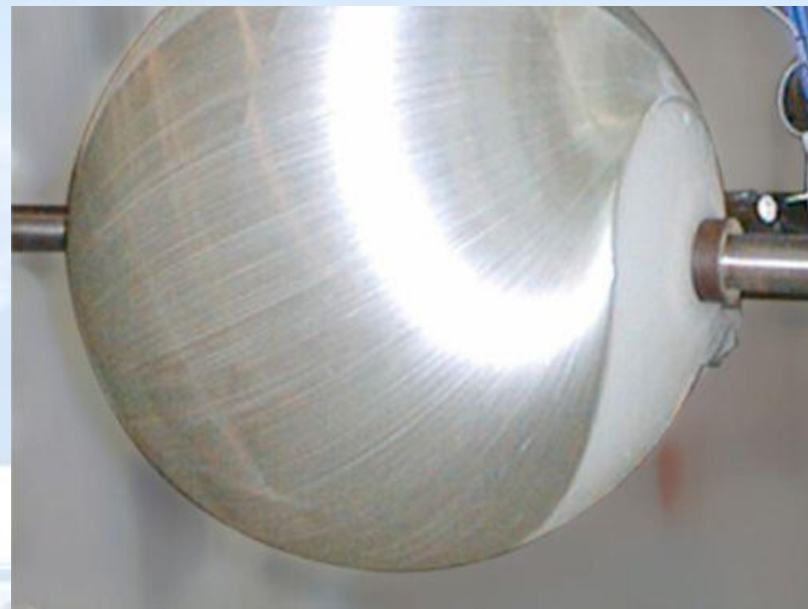
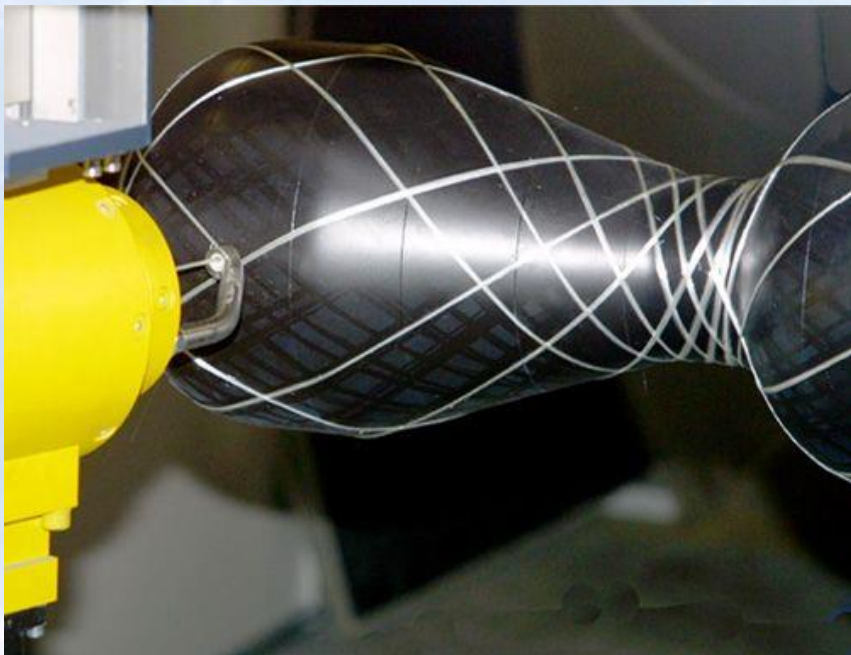
- Products made by filament winding are very strong
- Filament winding has also been used for strengthening cylindrical or spherical pressure vessels, Figure 5b, made of such materials as aluminium or titanium. The metal inner lining makes the part impermeable
- Filament winding can be used directly over solid-rocket propellant forms

Medium Capacity Filament Winding Machines - MAW20-MC



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Filament Winding

- Seven axis computer controlled machines have been developed for making asymmetric parts that automatically dispense several unidirectional prepregs
- Typical asymmetric parts made include aircraft engine ducts, fuselages, propellers, blades and struts

<https://www.youtube.com/watch?v=ign6W5ENJAA> how it works simulation of filament winding

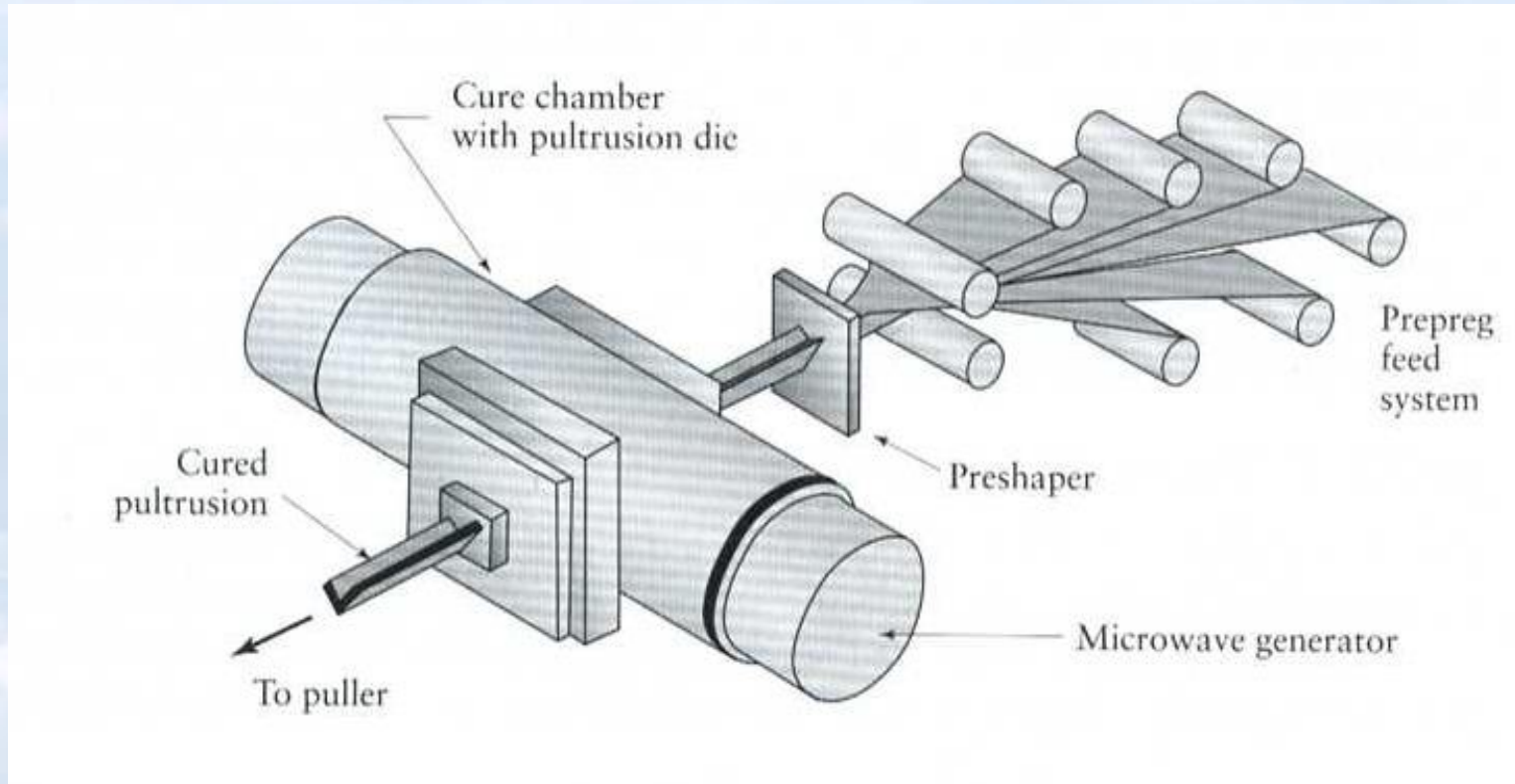
<http://www.youtube.com/watch?v=j19na8LMBnE> filament winding

<https://www.youtube.com/watch?v=VbYWd6NXAXk>

Pultrusion

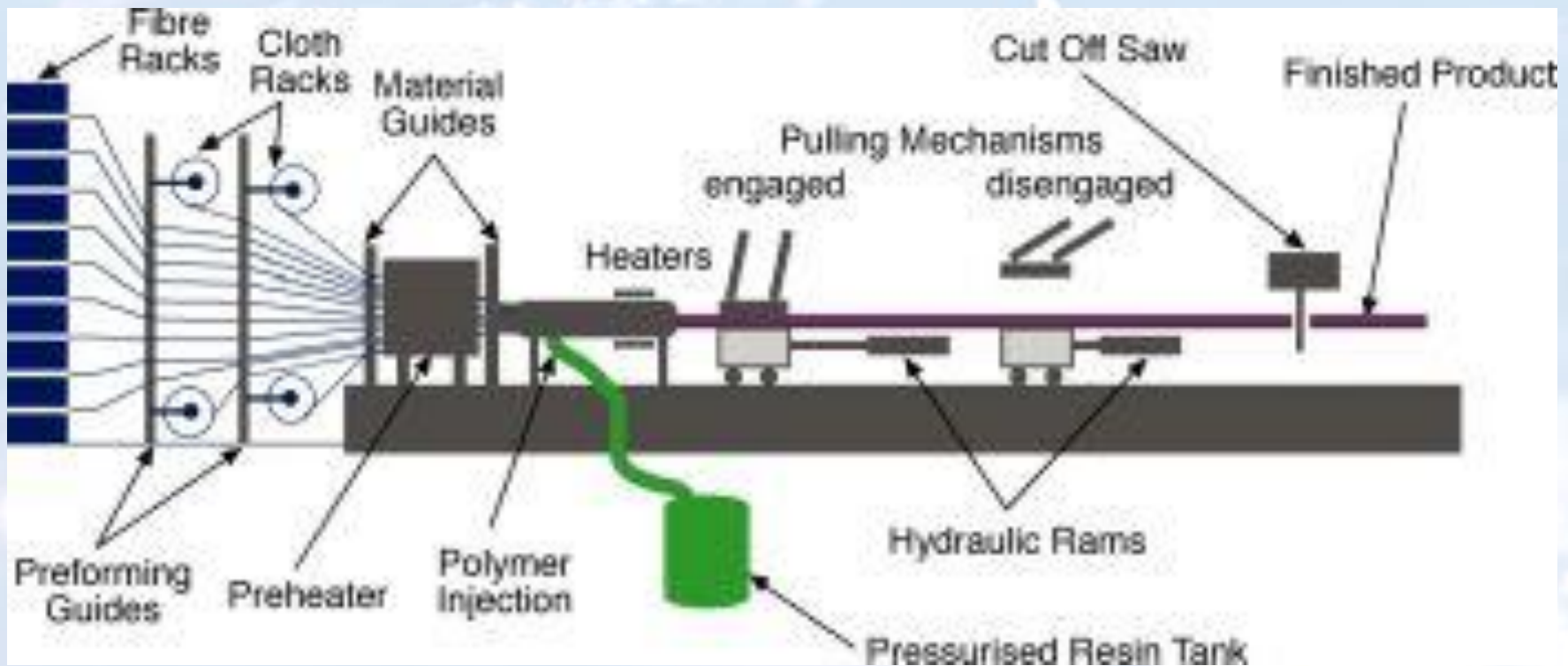
- Long shapes with various constant profiles, such as rods, structural profiles and tubing (similar to drawn metal products), are made by the pultrusion process, see Figure 6
- Typical products: golf clubs, drive shafts, structural members such as ladders, walkways and handrails. Most common material is polyester with glass reinforcement

Pultrusion Process Fig 6



The figure shows a micro wave heating arrangement, although curing can be performed in a heated die

Pultrusion



<http://www.youtube.com/watch?v=0ZhDWU9w048>

<https://www.youtube.com/watch?v=iQkwCv7dkSQ>

Pulforming

- Continuously reinforced products other than profiles with a constant cross-section are made by pulforming
- After being pulled through a polymer bath, the composite is clamped between two halves of a die and cured into a finished product
- The dies re-circulate and shape the product successively
- Common products: glass fibre reinforced hammer handles, curved automotive leaf springs

Morgan Sports Cars – Very Traditional Ash & Adhesively Bonded Aluminium Chassis

<https://www.youtube.com/watch?v=OJLcoGMPQ94> Morgan manufacture



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End